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TABLE OF CONTENTS

Officers for 1911-12 iii
Standing and Special Committees v
List of Illustrations xi
List of Tables and Diagrams xiii
Fire Line Meters. By George Houston 1
Discussion by:
Mr. Chester 5, 13
Mr. Griswold 5, 7, 9, 13
Mr. Houston 6, 13
Mr. Kunhardt 7, 9, 10, 11, 18, 19
Mr. Caulfield 10
Mr. Walter Watson 11, 12
Mr. Hawley 16
Mr. Reimer 16
Mr. N. S. Hill 17
Mr. Thomas 19
Mr. E. E. Davis 20
Mr. Gwinn 21
Mr. Diven 22
Mr. Blauvelt 22
Pumping Station Management in Milwaukee. By Thomas McMillan 25
Discussion by:
Mr. Chester 36
Mr. McMillan 37, 38
Mr. Metcalf 37
Mr. Gwinn 37
Mr. Machen 38
Restoration of Old Distributing Systems. By Burt B. Hodgman 39
Discussion by:
Mr. Dunham 47
Mr. Hodgman 48, 49, 50, 51, 52
Mr. Chester 48, 50, 51
Mr. Hodgkins 49
Mr. McMillan 50
Mr. Worrell 50, 51
Mr. W. Z. Smith 52
Mr. Wehr 53
Discussion on Panama Canal. By Mr. Dabney H. Maury 53
Some Fundamental Consideration in the Determination of a Reasonable Return for Public Fire Hydrant Service. By Messrs. Metcalf, Kuichling and Hawley 55

Discussion by:
Mr. Metcalf....117, 141
Mr. Kimball....119
Mr. Knowles....122
Mr. Maury....128
Mr. Chester....130
Mr. Gwinn....132
Mr. I. B. Brown....133
Mr. Jordan....133
Mr. Hawley....135
Mr. T. C. Hatton....137
Mr. Salmon....138
Mr. Reimer....140
Mr. Blauvelt....141
Mr. George W. Booth....143
Mr. Alvord....145
Mr. Worrell....146
Mr. Benzette Williams....146
Mr. Dunham....147
Emergency Intakers. By Dr. W. P. Mason....151
Discussion by:
Mr. Knowles....152
Mr. Bass....154
Mr. Ellsworth....154
A Stand Pipe Accident. By H. C. Hodgkins....157
Wood Stave Pipe. By T. Chalkey Hatton....161
Discussion by:
Mr. Diven....170
Mr. Wehr....170
Mr. Metcalf....171
Mr. Hatton....171, 172
Mr. Van Gilder....172
Mr. Geager....172
Water Rates. By George G. Earl....173
Discussion by:
Mr. Alvord....189
Mr. Leisen....189, 198, 201
Mr. Bemis....195
Mr. Watson....198
Mr. Chester....198
Mr. Benzette Williams....201
Mr. I. B. Brown....203
Mr. Hodgkins....204
Mr. Dunham....205
Mr. Sherman....206
Mr. Trautwine....207
Mr. Hering....210
Mr. Earl....213

Steel vs. Cast Iron Pipe. By Allen Hazen....217
Discussion by:
Mr. S. N. Hill, Jr....224
Mr. Dunham....229
Hot Water Trouble. By George C. Whipple....231
Discussion by:
Mr. Diven....279
Mr. Hering....281
Mr. Speller....283, 286
Mr. Chester....285, 289, 290
Mr. Fisher....286
Mr. R. S. Weston....287
Mr. Whipple....289
Mr. Berry....290
Mr. Steadman....291
Mr. E. E. Davis....291
Mr. Gwinn....292
The Interpretation of Water Analyses. By Daniel D. Jackson....293
The Purification of Drinking Water. By Dr. John L. Leal....299
Discussion by:
Dr. Bartow....314
Mr. Bass....315
Methods of Keeping Records of Improvements to Establish Water Works Plants. By Charles Carroll Brown....317
Discussion by:
Mr. Gwinn....329
Public Utilities. By John C. Trautwine, Jr....331
Compressed Air in Water Works Construction. By Alexander Milne....337
Discussion by:
Mr. Milne....339
Sterilization of Water by Ultra Violet Rays. By A. E. Walden and S. T. Powell....341
Water Softening by Means of Zeolith. By Boris N. Simin....347
Some Water Works Experiences in India. By R. W. Lawton....353
The Investigation of Underground Water Waste in Washington, D. C. By W. A. McFarland....361
Stripping Reservoir Sites at Newcastle, England. By H.G. Coventry....367
High Service Fire Service Compared with Portable Fire Engines. By Charles A. Hague....369
Sydney Water Supply, Its History and Management....393
Question Box....425

ILLUSTRATIONS

Frontispiece.

Portrait of President—Mr. Alexander Milne.

Pumping Station Management in Milwaukee

Plan North Point Pumping Station....28

East Elevation North Point Pumping Station....inset facing, 28

The Restoration of Old Distributing Systems

Hose Stream Before Cleaning....42

Hose Stream after cleaning....42

A Stand Pipe Accident

Ruptured Stand Pipe....158

Hot Water Troubles

Tank System....236

City Pressure System....238

Dead End System....238

Circulating System....239

Supply for a large Building....240

Purification of Drinking Water

Portable Sterilization Plant....313

Sterilization of Water by Ultre Violet Rays

Domestic Sterilizer....342

Water Softening by Means of Zeolith

Zeolith Water Softening Plant....350

Plant in a Bremen Textile Mill....351

Some Water Works Experiences in India

The Tank or Reservoir....356

Steel Structure for the Support of the Reservoir....358

Sydney Water Supply, its History and Management

Cataract Dam under Construction....396

Cataract Dam under Construction....397

Cataract Dam under Construction....398

Valve House and Basin at Head of Lower Canal....401

Six-foot Trunk Main....403

Screening Chamber and Penstock....405

Screening Tank, Potts Hill....407

TABLES AND DIAGRAMS

THE RESTORATION OF OLD DISTRIBUTING SYSTEMS

Diagram: Gauge Charts Before and After Cleaning 43

Table: Discharge and Frictional Loss Before and After Cleaning, and Increase in Discharge and Carrying Capacity — inset facing page 40

REASONABLE RETURN FOR FIRE HYDRANT SERVICE

Table: Hydrant Rentals in the United States 1908 57

Diagram: Quantity of Water in Million Gallon per day Required for Domestic, Industrial and Public Use, and for Fire Protection only 67

Table: Percentage Total Carrying Capacity Required for Fire Hydrant Service 70

Table: Relative Diameter of Main Required for Combined Domestic and Fire Service, and Domestic Service Only 71

Table: Gallons per Minute for Fire Purposes in Excess of Domestic Consumption 72

Diagram: Quantity of Water for Fire Protection Service Necessary for Congested Value District 75

Diagram: Per Cent of Total Carrying Capacity of Pipe System Required for Fire Protection 77

Table: Average Consumption in Cities of United States, England, France and Germany 78

Table: Relation of Monthly, Weekly and Daily Maximum Consumption to Yearly Average 80

Table: Subdivision of Cost of Water Works Properties — 81, 82, 83, 84

Diagram: Per Cent Total Capacity of Pipe Required for Fire Protection, and Per Cent Whole Cost of Distribution System and of Fire Service and of the Total Cost of Water Works 85

Table: Cost of Portion of Water Works Plant Chargeable to Fire Protection Service 86

Diagram: Portion of Total Cost of Water Works Necessitated by Fire Protection Requirements 87

Table: Fire Tax and Waste in United States 88

Table: Per Capita Cost of Public Fire Hydrant Service 93

Table: Relation Between Per Capita Cost of Hydrant Service and Cost per Hydrant 94

Table: Percentage of Different Sizes of Pipe Used 96

Table: Miles of Pipe of Different Sizes 97

Table: Fire Insurance Data for Massachusetts 98

Table: Fire Insurance Data, Pennsylvania Water Co. 100

Table: Fire Loss in Greater New York 101

Table: Feet of Pipe to Fire Hydrants 106

Table: Areas Served by Hydrants in Different Districts, Average Number of Hydrants per mile and Percentage of Different Sized Pipes — inset facing page, 108

THE RESTORATION OF OLD DISTRIBUTION SYSTEMS
Diagram: Linear Hydrant Spacing for Congested and Residence Districts....follow page 142
Diagram: Area Served by each Hydrant Congested and Residence District....follow page, 142
Diagram: Gate Valve Spacing for Congested and Residence Districts follow page 142
Three diagrams by Geo. W. Booth as Insets....to follow page 144
HOT WATER PROBLEMS
Table: Consumption of Hot and Cold Water in an Apartment House..233
Table: Comparison of Color Cold and Hot Water....251
Table: Increase in Color of Water in Boiling....251
Table: Analysis of Hot and Cold Water....253
Table: Equipment for Supplying Hot Water to Apartment Houses...254
Table: Effect of Alkalinity on Corrosion of Iron....260
Table: Analysis of Fresh and Old Extract of Leaves....261
Table: Relation Between Amount Sulphate Alumina Required to Decolorize and the Reduction of Alkalinity....263
Table: Color of Extract of Chestnut Leaves....263
Table: Relation Between Decolorization of Soft Water with Sulphate of Alumina and Reduction of Alkalinity....265
Table: Effect of Coloring Matter on Reduction of Alkalinity....266
Table: Reaction of Hot Alum Treated Water....268
Diagram: Acid Condition of Soft Water Treated with Alum....269
Table: Solubility of Dissolved Oxygen in Distilled Water at Different Temperatures and Pressures....271
Diagram: Solubility of Oxygen at Different Temperatures and Pressures....272
KEEPING RECORDS OF IMPROVEMENTS
Cash Disbursements and Voucher Record....319
Record of Pipe Laying....321
STERILIZATION OF WATER BY ULTRA VIOLET RAYS
Diagram: Results of Tests Made....345
SYDNEY, AUSTRALIA, WATER SUPPLY
Table: List of Reservoirs or Tanks....409
Table: Classification of Capital Expenditure....420

FIRE LINE METERS: A COMPARISON OF EFFICIENCY

By George Houston

The purpose of this paper is not to set forth any conclusions of the writer, as to the relative merits or efficiency of the different kinds of what are known or frequently alluded to, as fire line meters, but for the purpose of bringing out a general discussion of the question at this time, so that any municipality or water company contemplating the placing of meters on fire lines may be benefited thereby.

As most of the members of the Association are probably aware, there seem to be but two makes of meters that the underwriters will consent to have placed on what are known as sprinkler lines, without in some way making the insured party feel that his rate of insurance will be greatly increased, or the payment of insurance, in case of a fire, refused entirely, although they may have accepted his premiums as regularly as they came due and were tendered; and as one of these meters, with its registering device, requires so much room, and expense, to properly install, it is unnecessary to consider it for this class of service, so we have but one meter left.

This condition, above referred to, with reference to insurance, which seems to prevail in most of our cities, would appear to be entirely unjustified unless the insurance companies can show conclusively that this meter is the only one on the market that does not in any way impair the efficiency of a sprinkler service, or that it impairs it the least of any.

The reason they give for objecting to other types of fire line meters is that they are "trash catchers" and are liable to become obstructed to such an extent that the flow of water through them will be entirely stopped, thereby entirely destroying the efficiency of the system on which they might be placed; on the other hand they claim that this one meter has no "trash catcher" in its mechanism, and that in case of a fire where more sprinkler heads break off than can be supplied through the by-pass meter, the swing valve opens in the main line, and provides for an unrestricted flow of water (and

also trash) equal to the full capacity of the pipe on which it is located, and so insures an ample supply of water to all parts of the system.

Now, agreeing for the present, that their contention as to the flow of water (and trash) through this meter is well founded, and that both would pass through it unrestricted, in case of a fire, let us, with our minds perfectly unbiased and open to conviction, after we have briefly considered the general method or plan of a sprinkler system, go back to the trash, that this meter of all meters permitted to pass through its open way unrestricted, after a fire had broken out, and see if plenty of water is getting to the fire.

A sprinkler system, to be brief, consists of a main pipe or riser, going up through the building, from which, at the ceiling of each story of the building, arms or branches lead off along the ceiling, and from these arms other branches or arms of much smaller pipe lead off, at right angles to the main arm, every few feet, so that, in most cases the last extension is not more than one-half or three-quarters of an inch in diameter.

In most of the factories of our city (and we have some very extensive ones) the main arms leading off from the risers range from 2 to 3 inches in diameter, and through these arms must come all the water for the sprinklers, in case of a fire.

Now, going back to the "trash" which we left for a time, after we find that it has passed through the meter all right we follow its course, and as it travels very rapidly we soon see it reach the sprinkler arm, through which the water is rushing to the fire; and what is the result? Oh! nothing, only the complete plugging up of the pipe, entirely shutting off the flow of water through the arm, thereby enabling the fire to gain such headway that it could not be extinguished, and a total destruction of the plant.

The underwriters, and the manufacturers of this particular meter, will probably say that the foregoing is merely idle imagination, and suggestive of something that in all probability never would occur. To this anticipated reply we answer; it is not idle imagination, but on the contrary, is just what is said to have happened in the case of a large factory building in our city; with the exception that the whole building did not burn, as part of it was saved by the fire department, and a further exception that there was no meter on the line; which last exception, according to the insurance people's contention, would make conditions as nearly perfect as they could ask for; nevertheless the loss, as the writer has been informed, was over $90,000.

Now, for the purpose of comparison, let us again consider this same plant equipped as before, except that it has an 8-inch current meter on in place of the one first considered, and see what effect the "trash" that went through the first meter and plugged the sprinkler arm, shutting off the flow of water, thereby giving the fire full sway, resulting in the destruction of the building, would have had on the fire.

To do this it is only necessary to consider the area of the propellers in any of the discredited current meters, which is about 50 square inches, and compare this with the area of the trash that plugged up the sprinkler arm in the former case, which, in a desire to be fair, we will say was a 3-inch pipe, having an area of a trifle over 7 square inches.

Deducting the area of the trash that passed through the favored meter and caused the loss of the building, from the area of the propeller in the other class of meters (which would be fair, as it is granted that these meters would catch the trash and hold it) we would still have left, unobstructed, 43 square inches of the propeller area in these discredited meters, less the area of the shaft and other parts of the propeller, for which we will deduct another 7 square inches, still leaving 36 square inches of open way for water to pass through, unobstructed, to feed the 3-inch sprinkler arm that was entirely closed in the other case by reason of not having a "trash catcher" on the line, in the form of a meter, and granting further that the trash might stop the propeller of these meters, thereby reducing the flow of water about 1 per cent, we will ask you to decide for yourselves whether a sufficient quantity of water would or would not pass through to supply the sprinkler arm in question.

If it would, can we not rightfully conclude that the discredited meters are better for sprinkler systems than the one approved by the underwriters, for the very reason that the insurance companies condemn them, namely—they *are* "trash catchers," and would hold in check trash that would pass right through the approved meter and choke up the system, while at the same time they provide for a flow of water through them, sufficient to extinguish almost any incipient fire, after they have held up far more trash than it would take to plug up almost any arm on the sprinkler riser.

One of the representatives of an underwriters association informed certain members of our city council that in case any "trash catcher" meter was put on the sprinkler line to any of their risks and a fire should occur in the building so equipped, and it was found that the

water had been stopped by trash, his company would certainly object to paying the insurance, and when asked if they would object to paying in case there was a detector meter on the line that let the trash through and plugged the pipes, he answered, "they would not." When asked why his company would pay in the one case and object to doing so in the other; after he had previously admitted, with reference to the local case, that if one of the discredited meters, herein before mentioned, had been on this sprinkler line, it *could* have prevented the débris passing through it and still let enough water through to have extinguished the fire, he hesitated, but finally said in substance: "We would pay in the one case for the reason that the system was equipped with an *approved* meter, while in the other case it is an isolated one and might never occur again, and so could not be reasonably considered in discussing the question."

From the foregoing does it not appear that the efficiency of the meter does not control so much as some other features?

Following an idea suggested by the last above, will say that a number of our manufacturers, who had been notified to place meters on their sprinkler lines, took up the question of efficiency of the different types, and decided that they wanted another meter than the one approved by the underwriters, and took the matter up with one of the underwriters' representatives, and in due time were advised, as I remember, that the meter named could be used without having insurance rates raised, but that "They would endorse the policy against circumstances arising from the use of such meter."

This, of course, had the supposed desired effect, and brought an order to the office for another detector meter, as the owners did not care to take the risk on their insurance that such an endorsement might involve, notwithstanding the fact that one of the other type of meters was preferred.

In conclusion will say that while there are other features of the detector meter that might be mentioned for comparison, the writer feels that this one of efficiency, as to water supply, is of the greatest importance at this time, and that, if through this paper, a general discussion and investigation can be brought about that will finally result in municipalities and water companies, as well as individual buyers, having something to say about what meter they will use without being in danger of having insurance policies cancelled, or loaded up with a lot of meaningless clauses, his efforts will have been well rewarded.

DISCUSSION

Mr. Chester: Mr. President, with regard to the emphasis laid upon trash, it seems to me that trash is something foreign to what water companies should have in their mains. There are two kinds of water supplies, underground or naturally filtered, and surface water, with which latter I believe the author of this paper has been dealing, and which to be pure should be filtered, and if filtered, there will be no trash in it. That would certainly eliminate a large part of the objection to any kind of meters so far as trash is concerned. The only other improvement necessary is the complete isolation of our sprinkler systems from any use other than that for which they are established, enabling all valves to be sealed, and in such cases the necessity of any meter on a sprinkler system is largely obviated.

Mr. Griswold: Mr. President, may I be permitted to say from a fire protection view-point, that the insurance companies and the fire protection engineers object to any kind of a meter, and they do not expect to find any water service which is going to carry through it sufficient trash to stop the supply. If any such system of water supply as that should exist we would hesitate primarily to give any credit for the sprinkler system, because we would certainly expect that if the waterworks people permitted trash to flow through their distribution system we would certainly get it in the smaller mains of our sprinkler equipment, and therefore we would be very chary of giving any man credit based upon the idea of his being able to get water through an impermeable wall.

In these days of progress of the waterworks service it seems impossible that anybody should assume that their water supply is filthy or filled with trash, for if trash collects it will stop the service, and then the sprinkler service would certainly be made inoperative. I cannot understand why that position should be assumed. I might say further from the standpoint of a fire protection engineer that we are somewhat in the position of those people upon whom it is proposed by the federal and some state governments to place an income tax to apply to their income from whatever source secured. There is a good deal of a fight on that proposition. Now the insurance companies and the fire protection engineer do not want a meter on the service at all. We want no influences that will tend to retard the absolutely complete flow of the water supply. Like those upon whom it is proposed to place an income tax, if we have got to be taxed we would

rather be taxed with one class of meter than another class of meter. We have approved no meter, but we do say, as we also say in relation to hose coupling, or in relation to a fire pump, that this or that hose coupling, or this or that fire pump that we have examined will do as well as we can expect considering the retarding influence on the flow of water.

There is no special meter that is put up by the insurance companies as the only "IT;" and if the gentleman who has just spoken has had the misfortune to meet with insurance interests which are so seemingly hidebound and anxious to follow the letter of what they consider the law that they propose to cancel the policy if you put in any other meter than So and So's, they are assuming an authority which is beyond their jurisdiction. There is no insurance organization today that manages an insurance company that writes the policy; and the insurance company that writes the policy has the final say as to whether that policy shall be cancelled and for what reason. The only privilege that the insurance agent who issues the policy has with respect to cancellation is upon the discovery of a bad moral condition, or because of non-payment of premiums. No organization outside of the company itself has the broad privilege of cancelling the policy because somebody not controlling the business says it ought to be cancelled. Whoever or wherever these parties may be representing insurance interests who would assume to say, "If you do not put in So and So's meter we will cancel the policy," they do not have the support of the people who pay the loss when the loss comes.

Mr. Houston: For the purpose of being fully understood by every member of this convention, and also for the purpose of inducing further discussion by the gentlemen who have replied, I wish to state that I did not intend to make any assertion that could be construed as saying that insurance companies had threatened to CANCEL policies if So and So's meters were used. I do not think that any such statement is made in the paper.

The paper does state, however, that one of our maufacturers, who wanted to use a different meter than the *approved* one, took the matter up with one of the underwriters representatives, and in due time was advised that the meter named, could be used, without having insurance rates raised but that "They would endorse the policy against conditions arising from the use of such meter."

The only statements I have made, with reference to the matter, are those contained in the paper.

All that water works people want is what is absolutely fair from all standpoints, and I sincerely hope that we will be able to discuss the paper in a spirit of fairness, and without any attempt at the juggling of words, as it is a matter that is mutual between insurance people, the meter manufacturers, the insured and water works companies—both municipally and privately owned.

The paper also says that "One of the representatives of an underwriters' association informed certain members of our council that in case any trash clogged a meter which was put on any sprinkler line supplying any of their risks and a fire should occur in the building so equipped, and it was found that the meter had been stopped by trash, his company would certainly object to paying the insurance."

Mr. Griswold: I do not believe that the author of this paper has ever found within a city where the water supply covers the whole property that the insurance companies have ever said that they would not pay a loss unless some particular class of meter was put in.

Mr. President, with your permission there is a gentleman here who was one of the executive officers of the Boston Manufacturers Mutual Fire Insurance Company, and I would like to hear from Mr. L. H. Kunhardt if he is willing to express himself on this subject.

President Alvord: If there is no objection the courtesy of the floor will be extended to Mr. Kunhardt.

Mr. Kunhardt: I feel a little diffident about saying anything, gentlemen, but so far as our particular company is concerned and others in our association, we lay down rules and requirements for the government of our members such as we believe are to the mutual advantage of the members and the companies. It is wholly a question of mutual coöperation as to what is best; we carry that system of mutality so far that we believe we ought to, and we do obtain the coöperation of all who have to do with the fire protection of any particular plant. Accordingly we lay out fire protection systems such as will give the utmost efficiency under all conditions; and we do know that any device that may operate as a possible obstruction to a pipe is a hindrance to fire protection. Even a multiplicity of gate valves upon such a system is bad. A multiplicity of ordinary check valves on such a system is bad. A multiplicity of any devices no matter of what sort, that restrict the area of the pipes is always bad. That is why Mr. Chester said a few minutes ago that the complete isolation

of a fire protection system is desirable and proper. In this way the necessity of a meter is obviated.

Now this is the primary thing with which we start. If you can isolate a fire protection system you will not need to put any obstruction upon its pipes. We use our best efforts to keep the system absolutely independent so that it will be under control and you will know where you stand every minute. We try to get all detector devices with just as large openings through them as possible. We place a limit on the smallness of size that we think desirable for fire service connections, especially in large plants and where the values run up into millions of dollars. This minimum is $5\frac{1}{4}$ inches. One device that is made today has a $4\frac{1}{2}$-inch throat and we have suggested that that ought to be made at least $5\frac{1}{4}$ inches.

I want to emphasize the fact that we must have a clear and unobstructed entrance pipe into the fire system. Suppose we were to have one hundred sprinkler-heads in this room. If you had a device on the entrance pipe which was liable to get plugged up you would hazard the entire efficiency of the whole sprinkler system in this room; but on the other hand if you were to allow simply little pebbles, etc., to get in there, or even a little grass, or a little wicking, or something of that kind that has been dropped into the pipe when they were making repairs in the streets—if you would allow that stuff to come along through the system it would get into the sprinkler-heads and would obstruct and block up the little branches in a few places, probably *all the rest of that system would still continue in operation* and *the portion in operation would be efficient.* After the fire was over we might find seven or eight sprinkler-heads with little gravel stones or sticks in them stopping up the openings; but that would not mean that the rest of the equipment had not been doing as good service as ever. In hundreds and hundreds of cases sprinklers have done good service as compared with the few cases where the buildings may have burned down due to inefficient water supply or perhaps to some plugging of the pipes. In other words, keep in mind that it is the main pipe that you are talking about when you are considering the placing of a device outside on the six inch pipe, and in that case you want to be very careful to see that there is no possible obstruction. It is the entrance pipes that are far more important than the branches.

There is another device that comes along with the ordinary meter that I might speak of, namely, the strainer. The holes in that strainer are perhaps $\frac{1}{4}$-inch in diameter, and you can see how quickly little particles may enter in and fill up these. It is not only when the fire

is occurring that filling up may occur. It may be under certain circumstances that sediment has been collecting for weeks or even months under small consumption, and it is not until the heavy demand comes along that you find the water will not flow through as it should, due to restricted area at the pipe entrance. Because of this the pressure at the sprinkler-heads may not exceed 10, 15 or 20 pounds on the first floor whereas the pressure in the street may be 50 or 60 pounds and there might be, therefore, no adequate supply whatever on the floors above. Furthermore the steam fire engines or hose streams may have reduced the pressure considerably below this due to the fire, so that the sprinklers in the fourth, fifth or sixth story would perhaps just barely have water enough to supply them on account of reduction in the pressure. Now, in such a case if there is in addition an obstruction in the pipe, the sprinkler-heads on the top floor will not receive any supply whatever, and the natural conclusion of the inexperienced is that that particular sprinkler system was not of any account. Strictly speaking, it was not doing any good, but it was not the fault of the sprinkler system, it was the fault of the devices on the bottom of the riser which prevented the sprinkler-heads from doing good work, which they otherwise could have done.

Mr. Griswold: I have already made the statement that the insurance interests have not issued an edict of approval of any one man's device. Fire insurance engineers and fire protection engineers test all meters, and if the tests show that they obstruct the flow, or if there is trash in the water system and it goes through a six inch connection it will find its lodgment in one branch perhaps, or two or three branches; but it will not cut-off the whole supply. Under the same conditions a meter with a strainer or trash collector may shut off the whole supply. I would like Mr. Kunhardt to say for the benefit of members present whether his companies, in which the insured are all members, have issued any edict of special approval of any meter. I do not think it has, but I would like to be informed.

Mr. Kunhardt: There has been no approval given to any meter. There have been circumstances where we have been obliged by the conditions to permit the use of a device on a fire protection system; but unfortunately there are meters on some fire systems in a few places that will cut off 40 or 50 per cent of the pressure sometimes. The current meter that was spoken of is not a circumstance compared with some of the obstructions that are on fire protection pipes in the

shape of meters. We do the best we can; we give our members the best advice possible. We ask them to take such meters off for the benefit of their property. Sometimes we put in an additional fire pump. Sometimes we put in new tanks or something of that kind which will give a main supply of water independent of the obstructed source.

With regard to the cancellation of policies, there is nothing a man can do that will invalidate his policy except what has been referred to, increased moral hazard resulting in the likelihood that the man will intentionally burn down his plant. If such a condition could be shown to exist the man could not collect his insurance. Every man is expected when he has a fire protection system in his plant to use his best endeavors to keep that system in order. An unintentional failure to do this on his part or the failure of waterworks to furnish an adequate water supply does not invalidate the policy.

Insurance companies provide against these contingencies of every kind. They provide against lightning, fire, all kinds of accidents, etc. It is the effort of insurance companies to reimburse the policy-holder in the event of loss. You never need fear when you hold an insurance policy that you cannot collect that policy if the insurance company is sound and solvent. Their effort is always to help the man, and on the other hand the policy-holders should help us to keep their risks up to the highest moral standard. If the conditions get so bad at a plant or the hazard so increases that we cannot insure it, we advise the policy-holder; the policy has a clause in it which states that after ten days' notice from the insuring company the policy may be cancelled, and the policy-holder is then obliged under the law to provide himself with other insurance at the expiration of the ten days.

Mr. Caulfield: I would like to ask if your company does not require three separate systems for water supply, that is, a pressure tank, a storage tank and a direct connection with the water mains? These are required in Minneapolis and St. Paul. I know of firms that have from 8000 to 12,000 gallon pressure tanks, 30,000 gallon storage tanks, and also direct connection from the water mains. My theory has always been that upon a fire occurring if these tanks are exhausted and the automatic sprinkler has not put out the fire the building by that time will be pretty well gone. They claim that they require three separate water systems.

Mr. Kunhardt: The matter of three systems is really the outgrowth of conditions. Now as a matter of fact any insurance com-

pany will accept two ample sources of water supply. The reason that they wish to have two is that they want to provide for the contingency that one source may be accidentally shut off or out of commission. They want two strings to their bow. The tank may have to be repaired, or cleaned and painted if it is a steel tank, both inside and out, and they want the city water supply to be available during that time. On the other hand, occasional repairs have to be made in public streets and the water has to be shut off, and during that time the tank supply would be available. The outgrowth of the three supplies has been this, I think: Suppose the plant had originally a public water service connection. We will say that there is a 12,000 gallon pressure tank. It has been found that a high pressure service tank with 100 pounds pressure is very limited in capacity, and when you come to pour its water contents on the fire under 100 pounds pressure, the ordinary sprinkler system will consume 15 to 20 gallons per sprinkler-head per minute, or say 20 gallons of water as a fair amount to bank on. With fifty sprinkler-heads open that would mean 1000 gallons per minute. A 12,000 gallon pressure tank only holds 9000 gallons of water, the remainder being air, and that will last only nine minutes when fifty sprinkler-heads are open. If only twenty-five are open it will operate for eighteen minutes. Experience has shown that this is not a very long time for the sprinkler to be doing good and efficient service. The effort, therefore, has been to get a little more water, and this has usually taken the form of a gravity tank. Suppose such a tank contains 30,000 gallons of water which will be delivered at the sprinkler-heads in the top floor under pressure of 15 pounds. That means at that lower pressure the water will last a longer time. Experience has shown that a pressure of 15 pounds is almost as efficient in a sprinkler system as 25 pounds, but it won't be quite as snappy.

Mr. Watson: What, if any, action do the insurance people take to prevent the consumer from tapping from the fire line.

Mr. Kunhardt: We are always up against the same proposition that you are more or less, of looking after our fire system, and we are doing it continually. We are continually advising against tapping. We are continually recommending taking off these connections when they are found. We know just as well as you do that one of the things that obstructs a sprinkler system is barnacles, rust and corrosion in pipes. You take a $\frac{3}{4}$-inch or 1-inch iron pipe into a building and run

water through it, before long the pipe is corroded and this would make the sprinkler system of no value.

We are just as desirous of having our sprinkler system as free and independent of all kinds of taps as you are, and we are trying to work with you all on that proposition. Any time that any waterworks man ever comes to us and says, "Gentlemen, I want to have a separation made down here in this plant, I am going to require it," we say to him, "We will help you. If it is your rule that you require that, we will be glad to conform to it." We sent out men to try and find out how to make your fire systems as efficient as they possibly can be. There are old systems in many places—I could mention dozens of them—one of them a big plant in the east that is worth $5,000,000. Twenty years ago it was probably worth $1,000,000, perhaps not so much. In those earlier days they made an agreement with the water company. The water company was a private company, and they agreed that they would pay a certain amount for the use of the water. There was no objection in those days to connecting up with a 6-inch fire line; taps were made to the closets in one part of the yard with a $1\frac{1}{2}$-inch pipe. The plant grew all the time until the water that the water company was furnishing amounted to perhaps $2000 or $3000 worth, for which the plant was only paying perhaps $700 under the old arrangement, simply an agreement made in writing that they were to pay $700 a year. The water company made up its mind one day that now that they were filtering their water and making it better than it ever was before, that they could not afford to furnish so much water as that at that price, and they notified the company accordingly. They also notified them to take every single connection off of the fire lines and put it on a separate line of pipe and meter the separate line, so that the fire protection system would be independent and unobstructed.

Mr. Watson: I have endeavored in my connection with my water company for ten years to treat the insurance people the best we could. In one case they have asked for a 6-inch line without any obstruction in any way; but I have found in the last three or four months that it is absolutely necessary to have something on that fire line to measure the amount of water that passes through it. In another instance we have a plant that has a 4-inch meter connection and our arrangement with them is that they are to pay us a minimum, and they are charged for the use of the water whenever they need it. They pump their regular supply. Their 4-inch line comes off of our 6-inch fire line.

Now for the past two years that 4-inch line has not been opened. It is metered. The other day one of our large trunk lines had to be shut down. We did not suppose that plant was using any water for their boilers from the fire line. It is a long line and passes around through the plant, and the superintendent told me, and I believe the thought he was telling the truth, that they didn't take any water from their fire line; but one of the foreigners that worked for them came over to the other side of the river and told one of our men that at the time our large trunk line was shut down that plant hadn't any pressure under their boiler.

MR. GRISWOLD: How was it that the matter run along for two years and you didn't know it?

MR. WATSON: Because they pumped their own water. They had several sources of supply.

MR. CHESTER: If a company starts out to steal water they will go to some main where there is no meter to show that they are stealing. The fact that there was no meter on the fire line permitted them to connect to the fire line. If there had been a meter on the fire line they would have gone to the main back of the meter. I think that is the way a thief generally does.

MR. HOUSTON: In the paper the assertion was made that the underwriters objected to all except one type of meters. We are digressing from that phase of the question quite materially, and I wish to recur to it and set the matter before you in the proper way. And in support of the assertion referred to wish to present the following extracts from correspondence with insurance men, one underwriter writing in part as follows:

> Against the consequences of the use of the ———————— meter manufactured by the ———————— Company, but did not object to the ———— meter made by the same people. Would also accept the detector meter made by ———————— Meter Company, and would object to the ———————— meter made by the same Company.

Also in said correspondence occurred the following language used by the underwriters' official:

> My opinion would be that placing either of these meters on would cause the insurers of the lumber to endorse the policies declining liability in the event of

a loss being traced to clogging of the meter, and I would certainly advise our people to endorse our policies similarly against the contingency of the exposure affecting the sprinklered buildings.

The mayor and water committee held a conference with an official of the Western Factory Insurance Association.

During the discussion the said insurance official made the assertion, with reference to a large fire that took place in our city a few years ago which destroyed a large portion of one of our paper mills, that the failure of the sprinkler system to extinguish the fire was due to the fact that the sprinkler arm running into the portion of the building which was destroyed, became plugged up with trash that came in through the city mains, thereby cutting off the supply of water entirely through that branch of the sprinkler system.

He further stated that in their inspection of the system, after the fire, they discovered this "trash" and intended to preserve it, but that through some mishap it fell into a pool of slush and while they were quite sure that they afterwards recovered it, still none of them were quite willing to positively identify it.

He also stated that if they could have positively shown this trash came from the city mains, the city might have been sued for the full amount of the loss the company met with, which as he remembered, was about $90,000.

With reference to fire line services being used for purposes other than that for which they were intended, the speaker wishes to say that we have one company that has been using water through an exclusive sprinkler line, no domestic use being connected with it that we knew of. We installed a meter on the system and after about two days inspected it and found that they had used about 45,000 cubic feet of water through the sprinkler system alone in that time. They had an independent connection entirely for the office building and for the factory.

Following the discovery of the use of this great quantity of water through the fire lines, we started an investigation, and about the first thing that attracted our attention was the underwriters' pump, with which they were supposed to keep up the pressure required by the insurance companies, as their system was not equipped with pressure tanks.

This pump was a very rattly affair, rather antiquated in appearance, and was going full blast. We were told that it worked right along and gave excellent service.

We couldn't understand how such a pump could maintain the pres-

sure that their gauge indicated, and so looked around a little and found a pipe, that came in from an adjoining room, connected with the pipes on the pump.

We then had the gate on the main sprinkler line closed, and the pressure gauge at once dropped to 5 pounds, notwithstanding the fact that the pump kept on working just the same.

The line spoken of, we found to be connected with an arm of the sprinkler system in the next room, and they had it connected with the pipe on the pump on which the pressure gauge was located, and so in that way used the city pumps to keep up pressure instead of doing it with their own pump.

After making this discovery, we learned from some of the employees of the company that they had been carrying things on in this way for a long time, and that they had been using water in large quantities out of the sprinkler system in nearly all parts of the mill, having had, according to sworn testimony, as many as twenty-seven connections on the system at one time, these connections ranging, in size, from $\frac{3}{4}$ inch to 2 inches in diameter.

They seem to have had the spring in their pressure gauge so adjusted that it would show a pressure of 5 pounds, or more, higher than the system was actually carrying, which would cause a casual observer to conclude that they were maintaining a pressure higher than that of the city pumps, and that if they were using any water out of the sprinkler system it did not come from the city mains, but from their own pump, and by the way, I will say that this is exactly what they tried to make us believe.

By this investigation we discovered the fact that certain parties were not doing what they said they could and would do, as, notwithstanding the fact that underwriters' representatives have assured us all along, that they were our best detectors, because they had every sprinkler system thoroughly inspected with only short intervals between inspections, and if any irregularities were discovered, that would go to show that water was being used to any extent through the sprinkler system, for other than fire purposes, or that the equipment was inadequate—or out of order, they could and would under the contracts cancel the policy of such a risk, they have permitted the conditions, which prevail at this plant, to exist, and still they did not cancel the insurance or notify our city authorities of what was going on, and give us a chance to put a stop to this flagrant and illegal use of water, although the city was suffering from a scarcity of water at the time of the discovery, and had been for a long time previous.

The insurance companies succeeded for about ten years, in their effort to make our city councils believe that they were, on account of their requirements and rigid inspections, which I have just alluded to, better protectors of the city water supply than were meters, and it was only by a majority of one—the mayor having decided a tie vote of the council—that meters were finally forced on fire lines.

Mr. Hawley: It is evident that the paper under discussion confuses the functions of the two classes of meters, the detector meter and the current meter.

If a manufacturing plant is being supplied through one pipe for industrial purposes and also fire protection, there is the place to set a current meter. If our insurance friends do not like it so much the better. They will bring influence to bear to take the fire protection off the shop supply and put it where it ought to be, on its own separate line. A current meter is all right for shop supply under certain conditions; but when fire protection is taken from one line that line is no place for the current meter. It is not built for that service, while the detector meter is built for it.

We do not need to measure the amount of water used for putting out a fire; we do not care for that. What we want to know is whether any water is taken "surreptitiously" from the fire lines, and that we can find out by the detector meter; whereas the current meter, especially the larger sizes, may allow considerable water to pass without any registration. There is a service for which each class of meter is suited, but neither can do what the other is designed to do.

Mr. Reimer: Since the question has been raised by the paper read by Mr. Houston as to the methods used by the various insurance companies, I would state that some time ago in studying this question of fire line meters I found some peculiar cases which seemed to be contradictory of some of the claims made by the insurance companies. In a comparatively limited area I examined a number of fire line connections of various kinds and sizes. In the first half dozen cases investigated I found that the insurance companies were accepting the following conditions: Two lines were equipped with detector meters and large branch lines, the branch lines being fitted with ordinary current meters for measuring the normal use of water on the premises: two were found with sealed valves controlling the fire lines, that is, the valves on the fire lines were closed and sealed with the Water Department seal, these apparently acting just as well as detec-

tor meters, yet those lines were actually sealed against the passage of water, supposedly protecting highly valuable property with heavy risks involved; of the last two of the first six lines examined one had no valve or meter controlling the line and the other had been passed by the insurance company in the following condition. The 4-inch fire line coming into the main building carried a 1½-inch branch line. The Department finding that the piping throughout the building had been so arranged that there was a connection between what was supposed to be a fire line service only and the regular service line, simply put a 1-inch meter on the 4-inch line which was supposed to be for fire service. Yet that condition was accepted by the insurance company.

I did not go very much further in the investigation, deciding that if the insurance companies were willing to accept such conditions under their policies there was not very much use for worry on the part of the Water Department, so we simply adopted a certain policy and have pursued it regardless of what the insurance companies did or wished. If these companies will accept such conditions as we found in one small district I cannot see how they can raise much objection to what any water department may do.

Mr. N. S. Hill: I feel that the water department should be equally interested with the insurance company in trying to provide the best and most adequate fire protection; on the other hand, I feel that the insurance people should coöperate with the water department in preventing the meretricious use of water. Unquestionably there are today numbers of so-called fire lines from which connections have been taken. I have run into a number of them; and in some cases these connections have spelt the difference between profit and loss to small water companies. In taking up this matter it should not be a question of what the insurance companies have allowed or what the insurance companies have overlooked—but rather a question in which both the water company and the insurance company are vitally interested; viz. adequate fire protection with an assured revenue. The water department can coöperate and notify the insurance companies of conditions such as Mr. Reimer has described; insurance companies can act as a coöperative agency by notifying the water department whenever they discover the surreptitious use of water. Coöperation of this kind would tend more than anything else to establish a mutual understanding which would bring about that which is desired by all, namely, fire protection, complete and perfect as it may be made con-

sistent with the safeguarding of the water department from those losses which every practical waterworks man knows to exist.

So much for coöperation. On the one hand, meters on fire lines are absolutely essential in order to minimize the operating cost of the water department or water company and in some cases are even necessary to prevent losses to small works which mean financial ruin. The insurance companies must not impose conditions which cannot be met with in the practical design of a fire service meter. Meters may have been designed which will minimize the danger of stoppage and the insurance companies should take a rational view of the meter question.

On the other hand, the type of meter is of the utmost importance; and while at first I felt somewhat doubtful about the insistence of the insurance companies upon a type of meter which would do away with any restriction of the pipe opening, I have in looking into the matter found that the demands are reasonable from an insurance view-point, and I believe that there are enough cases in which overalls, pick handles and other implements, pieces of rock and hemp have been left in the pipe, causing serious trouble and stoppages, to justify the statement that it is certainly important that a meter or device which is used on a fire line should not be a trash collector. I think that the water companies should coöperate in helping the insurance companies to get the type of meter which they desire; and the meter companies should go to work and develop meters which will meet these conditions. It will not be long before the differences on the subject of fire service, which have existed between this association and the insurance companies, and which have been under discussion for a number of years will be settled.

Mr. Kunhardt: I wish most heartily to thank the gentleman who has just spoken, for his remarks, which are along the right line and represent just what we are trying to do. This proposition is a mutual one, there is no question about it; and there is also no denial but what obstructions do occur in pipes, we want to keep out any and all obstructions, whether they are overalls or something else. In Springfield, Mass., we found a 6-inch pipe going into a factory was obstructed. When we came to test it we could not get any water through it. In the endeavor to ascertain what the trouble was, we found something that would have operated against the detector or anything else. The 6-inch pipe came in at a right angle bend. We found a 6-inch log of wood there as large as the pipe. It had been stuck into the pipe when

the workmen left off work one night, and when they commenced work the next morning they left it in, and went ahead. It was a piece of wood 2 or 3 feet in length. It floated along till it came to this elbow beyond which it could not go, because it could not turn around the corner. Such cases of pipe obstruction occur in one way or another. And all of the fire protection engineers who can rightfully claim that title will coöperate in the matter of the proper arrangement of fire service connections. If they do not they are not fire protection engineers in the best sense.

There are many plants where for years and years they have been following old rules and regulations, and when the water department wants to change those things they have only got to say the word. In that case where they were found to have been using 45,000 cubic feet of water it would have been easy enough for the waterworks people to have been aware of that fact five years before even without putting a meter on. They could have found it out in many ways; by shutting and closing gates around in different places. The city of Lowell waked up one morning and found they had no water in their pipes at all. They hunted for several hours and finally discovered the leak in one of the mill wheel pits where a main had burst and was discharging into the Merrimac River. They didn't need a meter to find that out. Such losses you can always locate. As insurance people we want to help you, because we do not want this large use of water off of the fire protection lines.

Mr. Thomas: I want to correct one statement which the gentleman just made in regard to the city of Lowell waking up one morning and finding no water in its pipes. I have been connected with the waterworks there since 1887. I am perfectly familiar with the history of the water department from its very origin; I desire to say that there is no foundation at all in fact for that statement.

Mr. Kuhardt: I am going to make just one qualification of that statement, namely, that it was either Lowell or Lawrence. It happened many years ago, if I remember correctly. The story came to me from people who knew of it and who had lived in the place. Possibly it might have been Lowell, but it was either one or the other of those two places. They waked up one morning and found the water gone in the reservoir, and they did not know where it had gone.[1]

[1] Note by Mr. Kuhardt:—Upon investigation I find this incident occurred on the Lock and Canal system, which supplied water to the manufacturing district and was not a part of the city water works at Lowell.

Mr. Thomas: We have a 30,000,000 gallon reservoir at Lowell and Lawrence has a 40,000,000 gallon reservoir. I think it might have occurred with the company that was furnishing private fire connections for some of the mutual insurance risks. They had a little reservoir that held about 1,000,000 gallons. I know that was emptied after one fire; which would have burned down several mills if the city of Lowell had not come to their rescue and furnished water for sprinklers and hose.

Mr. Kunhardt: You see that we need the city water, gentlemen, that is just what we do need.

Mr. E. E. Davis: In a distant city, a great many years ago there was a large mill fitted up for fire protection with a 4-inch pipe and 3-inch outlet. The valves were the old-fashioned plugged cocks and opened with a lever. In those days they did not know what hose valves were like such as we have today. They invited the press and the public and everybody else to come down and see the grand fire protection they had there that would enable them to flood each of the floors. After the people were all assembled the men at the place were told to open the valves. When they went to open the cocks they found they had forgotten to grease the valve, and four men could not open one of the cocks.

Some years ago we had trouble with the insurance company who said they wanted the fire lines to be not metered. The chairman of our Water Committee said, "What does our superintendent say?" I said, "He wants meters on the fire lines." The chairman said, "What sort of a meter?" I replied, "Any good one that is acceptable to the water department; if the insurance company will tell me what kind of a meter they want I would be glad to take it up; but so far as I am concerned I require a meter on that line."

In the first place, when a line is put in it is expected that there are no connections allowed on that line except for fire protection, and in the second place, that no water is to be taken from that line except for fire purposes, and that a separate line with separate connections shall be laid for domestic use, so we can see that they do not use any water off that fire line. Several years ago there was a mill at Richmond with a tank on the roof supplied from the city service, the tank supplying the sprinkler system. The roof caught afire and burned up the tank.

The waterworks people endeavor in so far as they can to see that

the contractors carry out their contract as to the proper street connection. In one case there was a large mill fitted up with a 3-inch fire service that we required metered. When the meter was set the pipe extended up to the wall, and the contractor was to put it through the wall and connect with the pipe on the inside; but for some reason he never did connect it up on the outside but simply put a block behind the flange, and fastened the block up against the wall, and they tested out the fire lines from the smaller pipe with which he connected. Several years afterwards when the mill burned down we found that the pipe had never been connected through the wall.

We have had some peculiar experiences down there. We have a fire department chief with whom I worked in unison. We have an ordinance down there that requires that if a water bill is unpaid the water shall be shut off the premises. This necessarily shuts off the fire connection as well as the domestic supply, and whenever this is done the chief of the fire department is notified. On one occasion a theater there failed to pay their water bill for water consumed through their domestic supply. There being no water registered on the fire line the man told me that I could not shut his water off because it would interfere with his fire protection. I told him that the water would be shut off unless the bill was paid. He continued to refuse to pay his bill; so I sent a man to shut the water off of both the domestic and the fire line, at the same time notifying the chief of the fire department, who in turn notified the management of the theater that he could not hold any performances there until the water was turned on his fire line. Of course it was only a short while before he sent up a check to the water department for the amount of his bill.

Mr. Gwinn: I heard of a place where they depended upon a sealed valve in order to protect the water company. They had it in a nice little brick pit with iron cover. The waterworks inspector was in the habit of looking into the pit and concluding that the valve was sealed; one day they got a new inspector, who decided to examine a little bit closer than that, and he found that it was sealed all right, but that they had sawed off the stem of the valve just above the stuffing-box and had opened it, and so far as all appearances went it was still sealed, but nevertheless the valve was wide open.

Now as to the question of locating meters on fire lines, I thought that had gotten beyond the debatable stage. I prepared a list three years ago of over one hundred cities where they are using meters on fire lines, and I am a little surprised that anybody in this day and

generation would be willing to supply a fire line without placing a meter on it. I would not think of supplying any more fire lines unmetered; but there is a concern out at Terre Haute that have solved the question in such a way that it is not necessary to put any meter on. They have solved it so there is no danger of contamination, from the factory supply. The concern I refer to has solved the difficulty in its own way. It provides its own water, pumps it out of the ground and has its own tanks up on top of the building and does not have to get connection with the waterworks system—and I am mighty glad of it! We are a great deal better off without those connections than we are with them; but if we are going to have them, I would not think of having them without meters.

Mr. E. E. Davis: We do not allow a connection between the domestic supply and the tank supply.

Mr. Diven: I supposed that this question of meters on fire lines was settled in 1904. In 1903 we invited the insurance men to coöperate with us. We finally convinced them that there was such a thing as "mistaken" connections to fire lines—I will not say "stealing," but some employee would make a "mistake" and connect to the wrong line. We had a conference with them at two conventions, and finally adopted a detector meter as being mutually satisfactory. I am sorry to learn now that the detector meter is not satisfactory; but if the insurance people who are not satisfied with it have anything better to offer they will find this association ready to coöperate with them; or if they want to take the matter up again at a joint conference we will be glad to meet them at any time.

Mr. Blauvelt: It would seem fair to point out a wider range of facts applying to the general subjects mentioned therein, upon which this paper elects to be silent.

There is no necessity for fire underwriters doing business on the basis of city water supply at all. This is a matter for the property owner to choose and be governed by his own views as to the cost.

A minimum rate and preferred contract form, however, cannot be obtained from any class of insurance unless it carries with it precisely the conditions which that insurance prefers.

Anything over and above this must be paid or be waived for precisely as in all lines of business.

It is true as remarked by Mr. Kunhardt that the fire offices of great-

est experience do object to trash-catcher meters and do prefer to have the trash from the city mains come through a straightway connection and into the private mains at the risk of plugging up the sprinkler branch piping.

There is a long list of points which have developed in wide experience showing why this is the wiser course, however foolish it may appear from the view of a limited and local experience.

If the trash is permitted to come through it can be and is gotten rid of largely by blowing out hydrants or by opening up piping at periodical inspections.

Passing over this we always have the common law principle that whoever introduces a specific danger in company with a service and accepts pay for the service thereby becomes also automatically responsible for said danger accompanying said service, and particularly where it can be shown that the service was not rendered under the best possible state of the art.

This is why insurance interests at all times hold the right of subrogation as against any water works that may introduce a trash catcher into the fire protection line; or should the trash catcher be placed in the fire protection line under authorship of the property owner, then the same legal principle is an offset against full payment of loss under circumstances of an obstructed meter.

Most cases of insurance friction with waterworks arise from hasty action or a limited and local view of the subject.

The general subject of water supply to sprinkler systems is much beclouded by the idea that insurance companies desire to dictate, when they are simply declining added risk under their natural commercial interests, and heartily wish same could be left alone.

It is never fair, nor well informed, to treat public water supply in relation to private sprinkler system service as if it were merely a meter question, nor without bearing in mind at least six general considerations along the following lines:

No engineering nor fire insurance rate necessitates the use of public water at all.

City or public water is preferable only from property owner's point of view, and then only when obtainable at less cost than the interest and up-keep charges on a second source of private supply, the property owner being accustomed to provide one private supply irrespective of the use of the city water.

In the case of an unmetered connection furnishing pressure service to a sprinkler equipment carrying domestic excess pressure, for ex-

ample, the hundreds of equipments which have pressure tanks (which make water stealing wholly uncommercial on the part of the property owner) it is not fair nor good engineering to force any kind of detector or meter on the fire line.

A narrow or onerous rule as to meters and charges may have, and in important instances has had, the effect of causing property owners to completely sever their water department relations.

A minimum insurance rate, and what is far more important, the most free and desirable form of insurance contract, must not be looked for unless the insurance interests be given their choice as to how the question of trash shall be dealt with.

Insurance treatment of engineering questions is by no means confined to apparent acceptance or rejection of the conditions and is never a safe subject for opinion in a given case without a full knowledge of rate, contribution, adjustment, and subrogation rights under the contract.

PUMPING STATION MANAGEMENT IN MILWAUKEE

By Thomas McMillan

The object of this paper is an attempt to describe the practical operation of a pumping station. When a paper on engine room management was requested, the field was considered rather broad, as the successful operation of any engine room depends on local conditions, and these first of all must be taken into consideration. No two stations require the same management. The writer, while not opposed to labor saving appliances, considers that the operating engineer by looking out for small wastes, each not much in itself, but when combined, showing a fair percentage of saving, can lay out an excellent plan of work. The engine design may be of the highest type and of latest construction, but unless the small leaks, of which there are many, be headed off by the operators in the everyday management, the high efficiency will surely be impaired. The technical member has his place as also the practical man, and each may learn from the other something of interest, and for their mutual benefit. The pumping station is in a class by itself, what may be applicable or necessary in a central power plant with fast running machinery developing large power may not be necessary or even desirable in a pumping station with slow running machinery, and low in horse power. As the operation in one station, on account of local conditions must differ from another, the writer decided to give a plain statement of the mode of operation at North Point, the main pumping station of the Milwaukee water works, and the results obtained through a period of thirty-seven years' experience.

Before describing the manner of operation, it will be necessary to describe the local conditions under which it is managed and what led to the location on the lake shore with no railroad facilities for handling fuel at hand. This station is owned and operated by the city of Milwaukee under general supervision of the Board of Public Works, now Commissioner of Public Works and City Engineer, the latter having direct supervision of the water works system.

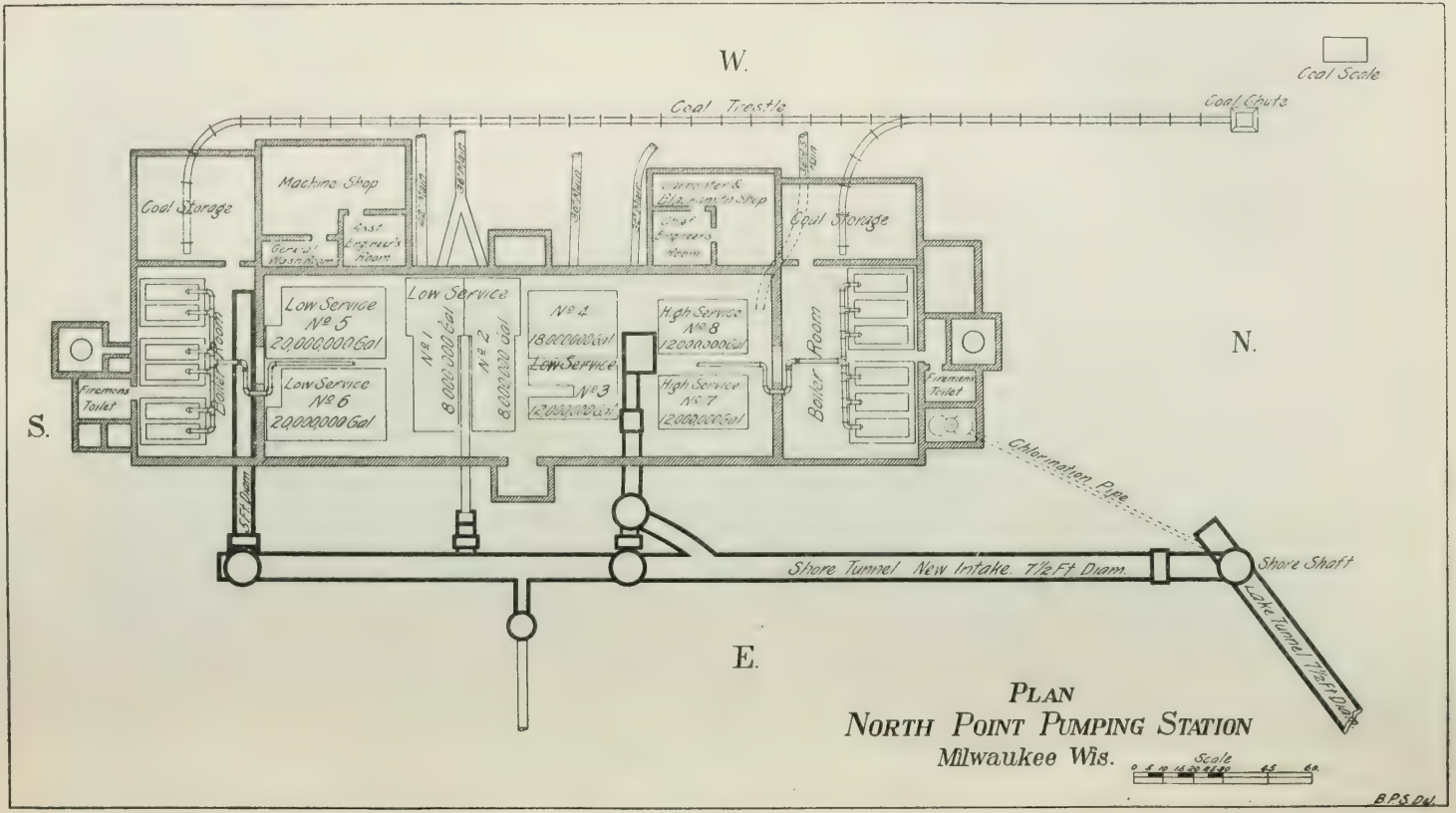
In the beginning (1872) two plans were considered. The present plan as carried out, and the other known as the tunnel plan which proposed locating the pumping station on the Milwaukee River about one mile from the lake shore. One advantage was considered if the station had been built on the bank of the river, coal could have been delivered in the stock house from a boat with considerable saving in handling, but when the extra cost of the tunnel was considered it was concluded that the interest on the investment would more than cover the extra cost of hauling, and it was decided to locate the engine house on the lake shore. The original engine room was built to accommodate four 8,000,000 gallon pumping engines. The principal cities of this country at that time were supplied with low pressure condensing beam engines, giving duties ranging from 45,000,000 to 60,000,000 foot pounds per 100 pounds of coal consumed. The first engines placed at North Point Station were a pair of compound beam engines, two 8,000,000 connected to one shaft and fly wheel and could be run singly or connected if desired. The steam was generated in four internally fired drop return flue boilers, the steam pressure being 55 pounds. The steam cylinders were not jacketed and the steam valves were balanced poppets, the duty shown on the test was about 75,000,000 foot pounds from each 100 pounds of coal consumed, the coal being egg anthracite. The station being situated in a good resident district anthracite coal was used, at a cost of $9.00 per ton of 2000 pounds, during the first year. During 1882 a vertical compound beam pumping engine was installed with a capacity of 12,000,000 gallons daily. Steam pressure was increased to 75 pounds and at the test the engine showed a duty of 104,000,000 foot pounds from 100 pounds of egg anthracite coal burned. This increased the daily capacity of the pumping station to 28,000,000 gallons. The daily consumption having at this time increased up to the capacity of the first engines installed. In 1891 a vertical triple engine was placed, of 18,000,000 daily capacity. This engine showed a duty at the test of 128,000,000 foot pounds for each 100 pounds of anthracite coal. Previous to this a north boiler house, coal house and chimney were built and a battery of five horizontal return tubular boilers $5\frac{1}{2}$ by 18 feet were placed in the north boiler room to carry a steam pressure of 125 pounds. Three years later the boilers were equipped with Hawley Down Draft furnaces and bituminous screenings were burned. The lowest price paid up to this time was $5.10 per ton for anthracite

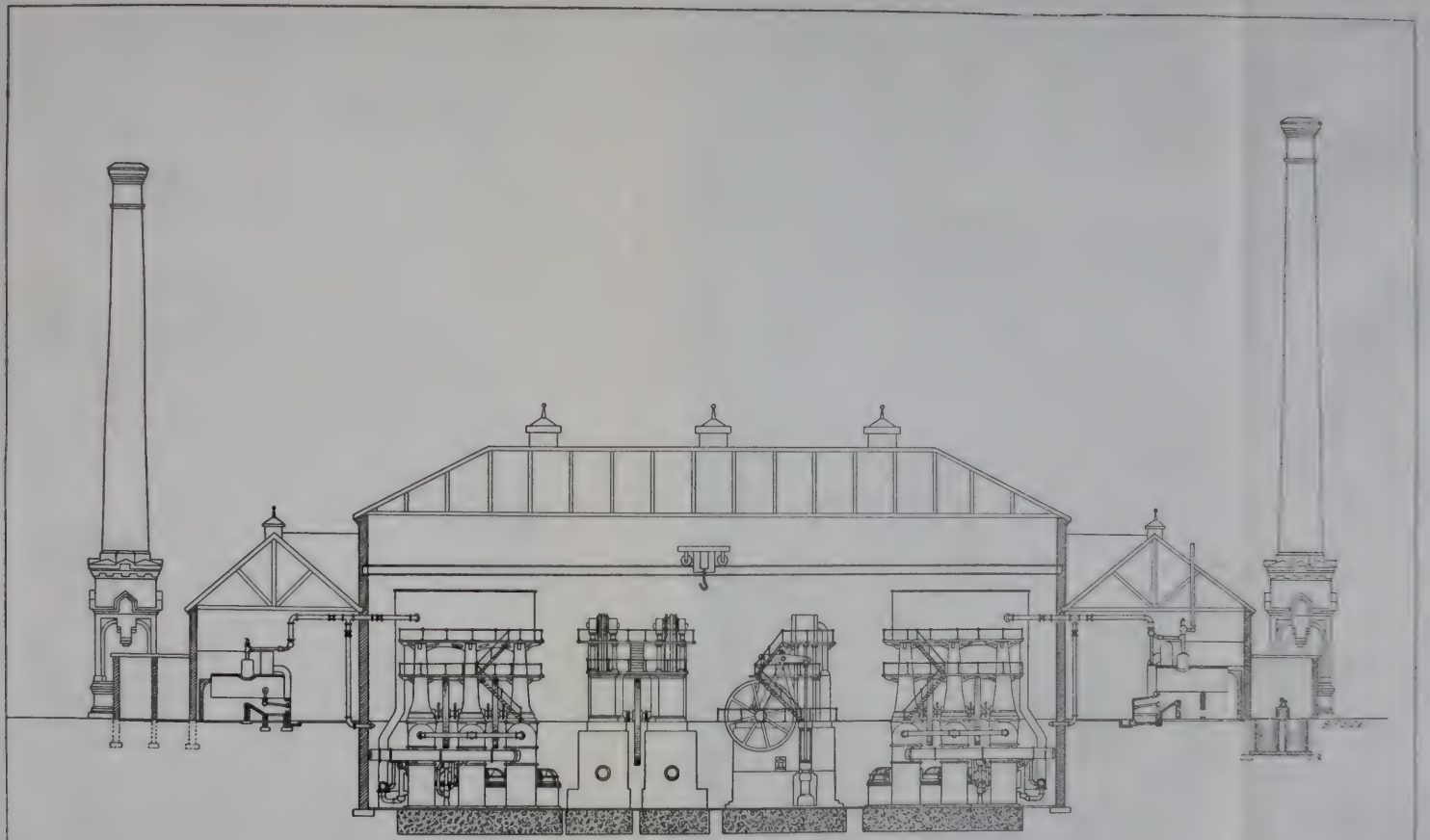
coal, and a few years later screenings were bought for $1.80 per ton, reducing the delivered cost of water about 10 per cent.

The capacity of the original engine house was now taken up with machinery, and, looking to future extensions, 62 feet of the south coal house was walled off for a boiler house, and in 1896 four horizontal return tubular boilers were placed therein, to take the place of the four original boilers which had passed their usefulness, to carry the desired pressure. During 1904 the south end of the engine room was carried over the old boiler room and space made for two 20,000,000 triple expansion pumping engines, the first of which was erected and put in service in 1906. Two additional boilers were placed completing the south battery of six. The original chimney was 50 inches by 120 feet high and was remodeled to 66 inches and 150 feet high. Another 20,000,000 low service engine was placed in 1908, both of these engines showing a duty of practically 165,000,000 foot pounds from 1000 pounds of steam, having not to exceed 2 per cent of moisture.

During 1908 the capacity of the high service station had been reached, it was decided to locate two 12,000,000 high service engines at North Point. Two-thirds of the coal house was walled off for a boiler room on the north end of the building and three 6-foot by 18-foot horizontal tubular boilers were located therein to carry 150 pounds steam, and the main engine room was extended over the old north boiler room. The first 12,000,000 high service triple expansion engine, to pump against a head of 275 feet, was placed in 1909 and the second 12,000,000 in 1910. These two engines showed a duty at the test of practically 175,000,000 foot pounds for each 1000 pounds of steam, not to exceed 2 per cent of moisture. The north chimney was also reconstructed and enlarged to 66 inches inside diameter and 150 feet high above the grates, three additional boilers being added in the north boiler room. The station as now completed comprises, an engine room 65 by 175 feet, a south boiler room 40 by 62 feet, a north boiler room 45 by 62 feet, two chimneys each 66 inches by 150 feet high and two coal rooms each with a storage capacity of about 450 tons of coal with the necessary work shops and toilet rooms as shown on plan.

The longitudinal section accompanying this article shows the position of the engines from the east side of the engine room and the location of the twelve boilers, six in the south boiler house and six in the north boiler house. A 20-ton electric crane travels over all the engines and was used in the erection of the last four engines


W.
Coal Scale
Coal Trestle
Coal Chute
Machine Shop
Coal Storage
Coal Storage
Low Service No 5 20,000,000 Gal
Low Service No 6 20,000,000 Gal
Low Service
No 1 8,000,000 Gal
No 2 8,000,000 Gal
No 4 18,000,000 Gal
Low Service No 3
High Service No 8 12,000,000 Gal
High Service No 7 12,000,000 Gal
Boiler Room
Boiler Room
Firemens Toilet
Firemens Toilet
S.
N.
Chlorination Pipe
Shore Tunnel New Intake. 7½ Ft Diam.
Shore Shaft
Lake Tunnel 7½ Ft Diam
E.
PLAN
NORTH POINT PUMPING STATION
Milwaukee Wis.
Scale
BPS DW



East Elevation
North Point Pumping Station.
Milwaukee Wis.

and also to facilitate repairs to existing engines. The following table shows the average daily pumpage, duty from total coal consumed for all purposes, grade of coal burned and average cost per ton through the several decades from the beginning, and the cost to deliver 1,000,000 gallons 1 foot high. This cost included wages, supplies, repairs, lighting, etc., all costs in the engine room from coal pile to force main.

DATES BETWEEN	AVERAGE DAILY PUMPAGE	AVERAGE DUTY FROM TOTAL COAL	COST OF COAL PER TON, 2000 LBS. AVERAGE	AVERAGE COST TO DELIVER 1,000,000 GAL. 1 FOOT HIGH	GRADE OF COAL
				cents	
1875–1880	7,500,000	64,000,000	$6 40	6 $\frac{10}{100}$	Egg anthracite.
1880–1890	17,250,000	80,000,000	6 05	5 $\frac{10}{100}$	Egg anthracite.
1890–1900	24,200,000	99,000,000	3 29	3 $\frac{40}{100}$	Screenings from 1894.
1900–1910	31,000,000	106,000,000	3 15	2 $\frac{90}{100}$	Pocahontas from 1908
Lowest record in any one year—1898.			1 94	2 $\frac{11}{100}$	Bituminous screenings.

In 1910 the average station duty was 120,000,000, using Pocahontas coal. In the last decade the station was operated under a disadvantage, portions of the building were taken down and rebuilt, steam pipes taken down and replaced and a part of the time steam was carried from the boilers to the engines across the open space and a large portion of the work charged to repairs. The works are now in normal condition and better results are looked for in reducing still further the cost of operation.

COAL

The nearest railway facilities are about three-quarters of a mile from the works, and constructing docking facilities on the lake front at that point would be too costly an undertaking, considering the amount of coal consumed. From 1875 until 1894, egg anthracite coal was used on account of the small percentage of smoke, but in the latter year, owing to the high price of anthracite and the increased amount used, Hawley Down Draft furnaces were placed under the boilers and Youghiogheny screenings used, being a good coking coal and suitable for such furnaces. It was found very satisfactory in the beginning. As the demand for screenings increased, however, the price advanced and the quality became inferior. In the western market merchants are allowed a certain per cent of screenings to the amount of coal bought and several varieties are mixed within

shipping range. Poor coking coal causing considerable smoke, it was decided in 1908 to demand Pocahontas or other coal of equal quality, of a good coking variety and to purchase on the basis of British thermal units delivered for one cent. The past three years coal has been purchased on this basis by yearly contract and hauled by teams to the works, delivered by the successful bidder into a chute adjoining the stock house. The coal is weighed on our own scales at the works. Tracks are laid from the chute into each coal house. The coal is taken from the chute by our own trimmer in dump cars each holding one ton. Cars are manipulated by hand, one man being able to deliver fifty tons daily into the coal house from the chute. Before the award of the contract, samples are tested of the coal proposed to be delivered during the year and the sample showing the greatest number of B.t.u. for one cent is accepted. This number is obtained by multiplying the number of B.t.u. in a pound of dry coal by the per cent of moisture (expressed in decimals) subtracting the product so found from the B.t.u. per pound of dry coal; multiplying the remainder by 2000 and dividing this product by the contract rate per ton (expressed in cents) plus one-half of the dry ash percentage (expressed as cents) which gives the number of B.t.u. for one cent. One-half of the percentage of dry ash is added to the price before dividing to compensate for the decreased burning efficiency of the coal in the furnace on account of the physical presence of the ash. During the delivery of the coal at the works, the weighmaster takes a small sample from each load as delivered and places it in a tight receptacle during the day and an average sample is taken therefrom for the laboratory test daily, and the average of such tests control the price paid during the month. After finding the B.t.u. per ton as delivered in the foregoing manner and dividing by the number of B.t.u. for one cent as in the contract guarantee, less one-half the per cent of dry ash, constitutes the delivered value.

In the proposals for the purchase of coal, specifications call for Pocahontas run of mine or equal, practically smokeless and free from excessive sulphur, slate or other refuse, as near the following quality as possible:

British thermal units	14,500
Moisture	2.5
	per cent
Volatile matter (dry)	18
Fixed carbon	75
Ash in coal	7
Sulphur in coal	1.25

The city reserves the right to reject samples having more than 3 per cent excess moisture or ash or less than 14,000 B.t.u. per pound of dry coal.

BOILERS

All of the boilers at North Point Station are of the horizontal return tubular type, equipped with down draft furnaces of the Hawley type, twelve in number, six 62 inches by 18 feet in the south battery, and six 72 inches by 18 feet in the north battery, located as shown on the plan and elevation of the works. All are hand fired and are operated under a working pressure of 125 pounds per square inch at the throttle. Under ordinary working conditions the evaporation is about 8½ to 1. One coal passer can deliver the amount of coal necessary on a watch, from the coal house in front of the boilers, and from two to three firemen according to the power demanded.

STEAM PIPING

The accompanying plan and elevation shows the arrangement of the steam piping. A 12-inch header of extra heavy wrought pipe with steel flanges and fittings extends the width of the boiler setting supported from the front walls, from this header a 12-inch branch extends upward and horizontal, to inside of the engine room wall and in line with the steam inlet to the high pressure cylinders of the two north and the two south engines. From the 12-inch horizontal branches extend downward in the boiler rooms to a line immediately under the main engine room floor and continue centrally through the engine room connecting the north and south batteries. The 12-inch horizontal lines are provided with stop gates in the boiler room and also the 8 inch branches so that the north engines may be operated from the south battery, or the south engines from the north battery of boilers, making for all practical purposes two stations under one roof. Stop gates are also provided in the 8-inch line under the floor between each pair of engines and a portion of the main steam line may be laid off for repairs, without interfering with the service.

BOILER FEED WATER

Each engine is provided with a boiler feed plunger pump attached to the main engine. The measured capacity of each being 25 per cent greater than the amount of water required to make steam to operate the engine. An open heater is placed centrally in the basement of

the engine room and connected to the hot well of the several engines, and all the feed pumps take feed water from this heater being placed two feet higher than the base of the feed pumps. The height of the water is regulated in the heater by a quick operating valve and float. No separators are used either in the steam line before entering the cylinders or in the exhaust pipes to the condensers, but the steam pipes are properly trapped at the lowest points, one each under the main headers over the boilers and two on the main steam line under the engine room floor. All of the traps return into the feed water heater together with the cylinder jacket condensation and the exhaust from the lighting and shop engine and heating coils during the winter, also when a boiler is laid off for cleaning, the steam is returned through a small bleeder to the heater. The temperature of the hot well water is about 90° at the overflow, but is increased from 150° to 175° before being returned to the boilers. To prevent as far as possible any oil or foreign matter being returned to the boilers a feed water filter is placed on the branch feed line from each engine. This is a simple arrangement, the water passing through the perforated cylinder covered with Turkish toweling. The current can be reversed in this filter for washing out, which is done about once daily, but the inner perforated cylinder is removed about once monthly and thoroughly washed. A spare cylinder being kept in reserve for that purpose. This operation can be performed in ten minutes, the feed water being bypassed in the meantime so it does not interfere with the regular feed. The firemen regulate the height of the feed in each boiler, but the engineer on watch regulates the quantity delivered by means of a bypass adjacent to the heater on the feed line, this water being returned to the heater and operated from the main engine room floor. With experience this is seldom touched oftener than once each watch, the water is kept at a stated height in the boilers allowing a little for blowing out once daily. All the triple expansion engines are provided with surface condensers. The early practice was to clean out a boiler monthly, but now when using feed water from the surface condensers it is found safe to run them six or even eight weeks without washing out. Each time a boiler is washed out all of the blow off valves are taken out by the boiler cleaner and examined by the engineer in charge. The valve used is a slow opening screw stem of the Y type with removable discs and found to give good satisfaction. The writer does not approve of a quick opening valve for the blow off, as it might cause a ram in the pipe when carelessly operated.

OILING SYSTEM

No automatic oiling system is used at this station. One oiler can do the oiling and wiping on two engines, and the writer considers one necessary even though equipped with an automatic system, as every automatic system observed by him did not extend to the valve gear and small bearings, consequently required hand oiling. It has been the practice here to use a good quality of lubricating oil and reduce the quantity used, a uniform system is established as found necessary by experience. The cylinder lubrication is only introduced into the high pressure cylinders, as enough lubrication is carried with the steam to the intermediate and low pressure cylinders and steam valves. An auxiliary cup is provided on all the cylinders, but it is never used except after a stop of some duration. The feed is regulated to a drop for a certain number of revolutions of the engine, usually about one drop to five or a little over a quart daily for each engine. The main bearings and connecting rods boxes are regulated to a drop in the same manner for a certain number of revolutions. The valve gear and small bearings are oiled three times each watch of eight hours. No lubricating compounds are used at this station, only cylinder and engine oils being used for lubrication. Up to the present time oils were bought in open market by the chief engineer, but it is now bought through a purchasing department in connection with all other supplies, used in the several city departments.

The average cost of lubricating oils during the last decade has not exceeded three cents for each million gallons of water pumped. The cotton waste used for wiping is a second grade white, and after being used on the main parts of the engines is placed in a receptacle in the basement for wiping the pump plungers and other parts of the machinery in the basement.

PACKING

All of the piston rods and valve stems are now packed with approved metallic packing. The pump plungers with the finest grade of flax which is bought in the rope form and braided at the works, in sections suitable for the circumference of each plunger. As the texture can be more readily seen before being soaked in lubricant, the sections are soaked in petrolatum and the side of the packing toward the plunger is smeared with Dixon's flake graphite before being used. Each alternate ring placed in the stuffing box

is of cast iron with water groove. The cast-iron rings are bored a littler larger than the diameter of the plungers, thereby reducing the friction on the plungers. This fibrous packing will last under ordinary conditions, from one to two years without renewal.

AUXILIARIES

Besides the feed pumps attached to the main engines, two auxiliary independent feed pumps are provided and are so constructed to pump from the pump wells and discharge into the overflow pipe or pump from the heater, and discharge into the feed line, but are seldom used. Two 25-kw. lighting units are provided, each capable of furnishing the lights or operating the crane, and can be run separately or together. A small engine is also provided to operate the repair shop tools, which consist of two lathes, a planer, drill press, etc., suitable for making all ordinary repairs at the works and also a small motor to drive the fan for the blacksmith's forge and a screw cutting machine which is placed in another room. The duties of several men employed at the station are of a general nature, five stations being under the one management and small repairs made for each. This would include the chief engineer, the assistant chief, machinist, blacksmith and carpenter, and such help as they might require as part of their time is taken up in the general upkeep of the other stations.

NORTH POINT OPERATION

Eight pumping engines are now installed at this station with a combined capacity of 110,000,000 gallons daily. Leaving out No. 1 and 2 compound beam engines installed in 1873, not now used in active service and only held in reserve, gives the station six engines in service with a combined capacity of 94,000,000 gallons daily. The maximum pumpage in 1910 for any one day was 55,000,000 gallons. The operating crew on a watch of eight hours is one engineer and one machinist who acts as second assistant engineer, three oilers, three firemen and one coal passer. All of the men change the time of their watch monthly, except the engineer in charge who is always on the watch from 6 A.M. to 2 P.M. and looks after the details of operation and keeps a daily record of the operation of the engines and boilers in a record book provided for that purpose. The other men who are on the morning watch one month are on the afternoon watch the next, and on the night watch the following month. The engineer

and machinist when changing from the night watch, works one month in the day hours on repairs. This keeps them in closer touch with the condition of the machinery and their hands in practice, all repairs being made by them. During the time of minimum pumpage, two oilers or two firemen are sufficient on a watch, and one of the number works on repairs or cleaning boilers, no special boiler cleaner being employed. This with the necessary helpers constitute the operating force on each watch.

IN GENERAL

All the men employed receive their appointment under city civil service rules. The engineers, oilers and firemen after a competitive examination. Promotions are allowed on recommendation of the head of the department after passing a creditable examination. From machinists to engineers, helpers to oilers or coal passers to firemen, and oilers may be promoted to engineers at the smaller stations. The engineers at the main station must have served an apprentice-ship as machinist before being appointed. On entering the service each man is provided with a book of rules defining his special duties in detail and what is expected from him during working hours. He is liable to suspension by the chief engineer for insubordination or any infraction of the rules or lack of good judgment in the performance of his duties, or may be dismissed from the service as the head of the department may determine. All the employes are well provided with toilet facilities adjacent to their work. The assistant engineers and machinists have their room adjacent to the engine room for lockers and washing, with shower baths. Immediately behind the south and north boilers the firemen have their rooms, also furnished with shower bath with hot and cold water connections. Each man employed is provided with a sanitary locker for which he retains the key while employed. No employe having access to the other lockers, each being provided with a Yale lock.

The extensions have been so rapid at this station during the past six years, remodeling the building and installing machinery and keeping up the supply, the whole city depending on this station, that some improvements in coal and ash handling have not as yet been reached. It is the intention during the present year to lay tracks from the stock house through the boiler rooms to the lake front for the more convenient handling of coal and ashes. In the extension of

the building it was the intention to have the new part harmonize with the original building with as few outward changes as possible. In placing the boilers in the original coal rooms the storage was reduced to one-third the original capacity, but this is not considered serious at present, as coal is delivered throughout the year. This, if necessary, can be remedied later by placing storage bins over the boilers, the walls of the building being sufficiently strong for that purpose.

DISCUSSION

Mr. Chester: Josh Billings said a good many years ago that "there is no use of arguing against success." I think that the discussion of this paper will be largely confined to commendation, or comparison of this station with other stations. Milwaukee has long been pointed to as a model, and we who have heard the paper today may better understand why it has furnished an example of economy as to fuel and other features of operation; and probably by a comparison with our own and other stations we realize why we have not obtained better duties. A gentleman remarked to me while the paper was being read that it certainly evidenced the disposition of the Scotchman to go into details. The duties obtained at this station are certainly remarkable, especially the station duties i.e., coal burned as compared with water pumped. I stirred up a tempest at the Toronto meeting, and again at Washington, by telling those who were in attendance at these conventions that I knew of no station pumping less than 10,000,000 gallons a day that produced 100,000,000 station duty.

One thing that impressed me very strongly was how Milwaukee can afford to buy Pocahontas coal, mined as it is in western West Virginia and eastern Tennessee. That is one matter that I would like the author of this paper to explain, although I have no doubt that under the careful system of buying coal they have worked out they have found it the cheapest, and it of course accounts in a measure for the high duty obtained. While I have no figures on cities nearby for later years, I have been going through some of the figures obtained at Chicago which show that no station there has produced over 75,000,000 duty; but I believe they use only Illinois coal, and naturally there should be an allowance of at least 20 per cent for Illinois coal, and even more than that allowance should be made when comparing with the Pocahontas or egg anthracite coals mentioned in this paper.

At Pittsburg we have coal that I think is about 10 per cent less in value and our station duty last year at none of the stations was over 90,000,000 duty. We are pumping considerably more water—when I say "we" I refer to the city of Pittsburg, I have nothing to do with that station—but we are pumping considerably more than the city of Milwaukee. I can only commend the manner in which the paper is gotten up and the subject that it has described, and the results that it shows as having been obtained.

MR. MCMILLAN: In regard to the cost of Pocahontas coal I think I explained pretty clearly in the paper that the actual cost in dollars and cents is a little higher with Pocahontas coal than with Youghiogheny screenings. I explained also that we are in the midst of a fine residence district and we must not make smoke. The head of the department and myself are both on the Smoke Commission, and we cannot make smoke; so that it costs a little more to burn Pocahontas coal than it would by using an inferior grade of coal. In looking over the records I find that Pocahontas cost 20 per cent more than Youghiogheny screenings, and we get about 15 per cent more efficiency, losing about 5 per cent to do away with the smoke nuisance.

MR. METCALF: The Association is certainly to be congratulated on this valuable paper by Mr. McMillan. It covers a wonderful record. I hesitate to make any suggestion; but it occurred to me as Mr. McMillan presented his paper, that it might add to the interest of one of his tabulations if he could give us in addition to the cost per million gallons of water pumped per foot in height the total cost including interest and depreciation charges per million gallons pumped one foot in height.

MR. MCMILLAN: We have never kept our records in that way, and I do not know that I can give you that very clearly.

MR. METCALF: It would be interesting to see how far increase in cost of plant, due to the use of higher types of machinery, tended to offset the cheapening in the cost of pumping water.

MR. GWINN: I think the city of Milwaukee is to be congratulated upon having so efficient a man in charge of their pumping station. They have also shown remarkably good judgment in keeping a man who understands his business, for a term of thirty-seven years.

MR. MACHEN: The author spoke of a central purchasing bureau I would like to ask whether that has been successful and whether that central purchasing bureau is inclined to overrule the engineer's order for material and furnish material which they as purchasing agents believe is more economical?

MR. MCMILLAN: The matter of a purchasing agent for the city of Milwaukee has not yet been finally determined. It is a new law which has only been in force for a few months during the past year. The matter of uniform classification of accounts is now in the hands of the Wisconsin railroad commission, but their report is not as yet rendered, but I may be able to give the information asked for later

MR. MACHEN: I ran across a case where a request was made for material and the purchasing agent said, "We want you to use a certain material that is satisfactory to us," and the engineer had to use it because he had no control over the central purchasing department. I wanted to know whether the purchasing agent would insist on the use of an article because they could buy it cheaper regardless of what the engineer's opinion was as to its real economy in use?

MR. MCMILLAN: So far as we have gone in that regard, in the matter of oils and such supplies, they usually come under the direction of the chief engineer. The purchasing agent consults the engineer on this point, and he does not force anything on us that is not satisfactory.

THE RESTORATION OF OLD DISTRIBUTING SYSTEMS

By Burt B. Hodgman

The restoration of old distributing systems is a subject which is coming more forcibly each succeeding year to the attention of superintendents, managers, and engineers having to do with water works operation. We have buried these systems with no thought of their tomorrow until it is evident from all the symptoms that the doctor is needed. Some of these symptoms are poor fire streams, dirty water after fires, high cost of pumping, and poor efficiency in general operation of the plant. Economy is the goal sought by operators in all kinds of industries today, but economy can only obtain through proper efficiency and efficiency in water works operation to a large extent depends upon the condition of these old distributing systems. How can these distributing systems be restored? Let us see the effect of sediment, scale and corrosion in the mains, and then look for the remedy.

Water conduits which have been down for ten, twenty, twenty-five years or longer have in most cases lost a considerable portion of their efficiency as carriers. This is due to the growth of organisms or the deposit of sediment or scale of one kind or another. It does not take a very large growth or deposit to seriously affect this carrying capacity, and this deterioration runs into operating cost very rapidly, as I shall attempt to show you in the brief discussion under the following heads:

1. The carrying capacity of dirty water mains compared with that of the same mains after cleaning, and with that of new mains of the same diameter and laid under similar conditions.
2. Economy of operation as affected by reduction of friction in pipe.
3. The useful life of cast-iron pipe as affected by cleaning.
4. Increase in investment due to cleaning.

1. THE CARRYING CAPACITY OF DIRTY WATER MAINS COMPARED WITH THAT OF THE SAME MAINS AFTER CLEANING, AND WITH THAT OF NEW MAINS OF THE SAME DIAMETER AND LAID UNDER SIMILAR CONDITIONS

A great many tests have been made to compare the discharge and carrying capacity of pipes before and after cleaning. These tests have been made in various ways. In some the flow has been measured by a 6-inch meter, in some with a pitometer, in some cases the pitometer and meter have both been used to check against possible errors, and in others the flow has been measured by nozzle discharge. The frictional loss has been measured by pressure gauges, and some times by mercury column, and the difference in levels between the testing points taken into consideration so that the exact frictional loss could be ascertained. The tests on folder facing page 40 will show some results which will be of interest and of value as bearing on this subject.

Referring to the tables it is worth while to mention particularly some few of these tests and explain the conditions under which they were made. Test No. 4 made in Brooklyn is a remarkable example of the effect of cleaning old pipes. The flow through 950 feet of 12-inch pipe discharging through an open end on to the street was measured before cleaning and found to be 1235 gallons per minute; while after cleaning it was 3754 gallons per minute. The frictional loss for the increased flow was 69 feet, compared with 98 feet before cleaning. Here was an actual increase in discharge of 204 per cent. Taking into account the frictional loss, the actual carrying capacity was increased 265 per cent. Another test worth noting was No. 12, made at Belle Plaine, Iowa, where the discharge before cleaning was 248 gallons per minute, but the frictional loss per 1000 feet was only 9.7 feet after cleaning compared with 39.8 feet per 1000 before cleaning. Again looking at test No. 21 made at Lockport, New York, where the same conditions existed and the same pressure was maintained at the pumping station before and after cleaning, the increase in discharge was 135 per cent. Perhaps the most interesting experiment of all though is recorded as No. 10, this test having been made on a 6-inch pipe at Perth Amboy, New Jersey. Here the incrustation which consisted of iron corrosion did not average $\frac{1}{4}$ inch in thickness and in the top of the pipe was not more than $\frac{1}{8}$ inch in thickness, and in some places even less, but the actual increase in discharge was 32 per cent, while the increase in carrying capacity was 51 per cent.

TEST NUMBER	LOCATION	DIAMETER OF PIPE IN INCHES	
		inches	
1	Philadelphia, Pa.....	6	
2	Brooklyn, N. Y.....	6	
3	Brooklyn, N. Y.....	8	
4	Brooklyn, N. Y.....	12	
5	Brooklyn, N. Y.....	30	
6	West Virginia.....	3.87	
7	West Virginia.....	5.93	
8	West Virginia.....	8	
9	Perth Amboy, N. J...	4	
10	Perth Amboy, N. J...	6	
11	Pittsburg, Pa.....	8	
12	Belle Plaine, Ia.....	6	
13	Western Pennsylvania.	6	
14	Western Pennsylvania.	4	
15	Troy, N. Y.....	6	
16	Camden, N. J.....	4	
17	Camden, N. J.....	8	
18	Cumberland, Md.....	6	
19	Madison, Ind.....	4	
20	Wheeling, W. Va.....	6	
21	Lockport, N. Y.....	6	
22	Little Rock, Ark.....	6	
23	Pittsburg, Pa.....	6	
24	Pittsburg, Pa.....	4	
25	Pittsburg, Pa.....	4	
26	New York City, N. Y.	6	
27	Rochester, N. Y.....	10	
		This t	
28	Atlanta, Ga.....	30	
		Pump against 1 against th	
29	Carbondale, Ill.....	8	
		In thi when disc ing, while	
30	Centralia, Ill.....	12	
		In this at pumpin cleaning w	

TEST NUMBER	LOCATION	DIAMETER OF PIPE IN INCHES	COATED PIPE?	LENGTH OF LINE TESTED	DISCHARGE IN GALLONS PER MINUTE		FRICTIONAL LOSS PER 1000 FEET		ACTUAL INCREASE IN DISCHARGE	ACTUAL INCREASE IN CARRYING CAPACITY	NATURE OF STOPPAGE	WHEN LAID	SOURCE OF WATER AFFECTING PIPES
					Before Cleaning	After Cleaning	Before Cleaning	After Cleaning					
		inches			*gals.*	*gals.*	*feet*	*feet*	*per cent*	*per cent*			
1	Philadelphia, Pa	6	No	447	384	710	120 0	46 0	95	215	Mud and iron corrosion	[illegible]	Schuylkill River
2	Brooklyn, N. Y.	6	No	806	176	623	73 0	81 0	254	231	Iron corrosion	1857	Ground water
3	Brooklyn, N. Y.	8	No	680	349	877	81 0	45 0	151	234	Iron corrosion	1857	Ground water
4	Brooklyn, N. Y.	12	No	950	[illegible]	3754	98 0	69 0	[illegible]	265	Iron corrosion	1857	Ground water
5	Brooklyn, N. Y.	30	Yes	1363	6050	7350	5 1	0 0		105	Pipe sponge and iron corrosion	186–?	Ground water
6	West Virginia	3.87	Yes	822		[illegible]		137 5			Iron corrosion		Ohio River
7	West Virginia	5.93	Yes	1050		725		56 8			Iron corrosion		Ohio River
8	West Virginia	8	Yes	[illegible]		1215		31 9			Iron corrosion		Ohio River
9	Perth Amboy, N. J.	4	Yes	500	247	477	166 0	145 0	91	105	Iron corrosion	1876	Ground water
10	Perth Amboy, N. J.	6	Yes	601	561	739	65 4	48 4	32	51	Iron corrosion	1876	Ground water
11	Pittsburg, Pa	8	Yes	3264	730	1620			121		Iron corrosion	[illegible]	Allegheny River
12	Belle Plaine, Ia	6	Yes	5044	248	335	39 8	9 7	35	174	Lime deposit	1902	Small creek
13	Western Pennsylvania	6	Yes	822		83		82 0			Iron corrosion		Allegheny River
14	Western Pennsylvania	4	Yes	1100		338		00 0			Iron corrosion		Allegheny River
15	Troy, N. Y.	6	Yes	410	443	703	94 7	46 0	59	130	Iron corrosion		Surface water
16	Camden, N. J.	4	No	420	100	227			127		Iron corrosion	1850	Ground water
17	Camden, N. J.	8	No		155	740			375		Iron corrosion	1846	Ground water
18	Cumberland, Md.	6	Yes	2200	403	802			100		Slime, mud and iron corrosion		Potomac River
19	Madison, Ind	4	No	924	90	262	102.0	90.0	191	211	Mud and iron corrosion		Ohio River
20	Wheeling, W. Va	6			320	890			178		Iron corrosion		Ohio River
21	Lockport, N. Y.	6	Yes	1100	315	742			135		Slime and iron corrosion	1875	Erie Canal
22	Little Rock, Ark.	6	Yes	1090	374	1021	154.6	96.8	170	344	Iron corrosion		Arkansas River
23	Pittsburg, Pa	6	Yes	[illegible]	252	671			166		Iron corrosion	[illegible]	Allegheny River
24	Pittsburg, Pa	4	Yes	1834	178	384			116		Iron corrosion		Allegheny River
25	Pittsburg, Pa	4	Yes	905	160	485			203		Iron corrosion	[illegible]	Allegheny River
26	New York City, N. Y.	6		650	435	765			76		Iron corrosion	1870	Croton River
27	Rochester, N. Y.	10	Yes	1045	1125	1740	48.0	30 0	55	110	Iron corrosion	1881	Genesee River
	This test both before and after cleaning included two 45 degrees bends and 45 feet of dirty pipe.												
28	Atlanta, Ga	30	Yes									1893	Chattahooche River
	Pump could only drive 11,880,000 gallons per 24 hours into reservoir before cleaning, and pumping against 110 pounds. After cleaning the line the same pump discharged 17,820,000 gallons per 24 hours, against the same head.												
29	Carbondale, Ill.	8	Yes	11,574	415	407					Clay mud scale	1897	Big Muddy River
	In this pipe water was pumped through 5000 feet of new 12-inch pipe also and total head pumped against when discharging into an open tank 45 feet higher than the pump discharge was 140 pounds before cleaning, while after cleaning the total head including the frictional loss was 48 pounds.												
30	Centralia, Ill.	12	Yes	11,000							Mud	1893	Surface water
	In this force main the average rate of consumption was 2,000,000 gallons per day, average pressure at pumping station was 90 pounds both before and after cleaning. Average pressure at City Hall before cleaning was 30 pounds and after cleaning 60 pounds.												

This goes to show that it is not the amount of volume taken up by the incrustation but the roughness of the surface which causes the trouble in these distributing mains.

I would now like to call your attention to tests Nos. 6, 7, and 8, where no measurements were taken before cleaning, but a very careful test was made after cleaning, because one of the requirements in regard to the cleaning of these lines was that they should have a carrying capacity after cleaning within 5 per cent of that of new pipe, of the same diameter. The carrying capacity in each case was figured by the Darcy Formula as used on page 77 of Weston's *Friction of Water in Pipes*. In test No. 6 the carrying capacity came within 3 per cent of that of new pipe. In test No. 7 the carrying capacity was 4 per cent below that of new pipe, while in test No. 8 the carrying capacity came within 1 per cent of that of new pipe of the same diameter. In regard to restoring the carrying capacity of mains it can be safely guaranteed that the capacity after cleaning will be within 5 per cent of that of new pipe, as figured by the Darcy Formula, providing that the pipes were originally coated, which is in all probability the case with water mains laid since 1870.

2. Economy of Operation as Affected by Reduction of Friction in Water Mains

There are so many different examples and demonstrations of reduction in operating expenses due to cleaning that it is hard to tell which are the most important to present. Among these I will call your attention to tests Nos. 28, 29, and 30. At Atlanta, Georgia, where a 30-inch main was cleaned the conditions existing were not uncommon or unknown in other plants. They had a large pump which was delivering water through this line at the rate of 11,888,000 gallons per day against a total head of 110 pounds, and they were losing water in their reservoir daily. By cleaning this line they were able to deliver 17,820,000 gallons per day against the same pressure an increase of nearly 6,000,000 gallons. Here it can be readily seen that not only was there great economy affected in operation, but had this line not been cleaned there would have been the necessity of laying new pipe, or of getting new pumps.

Again in test No. 29 made at Carbondale, Illinois, where they had reached a maximum pressure against which they could pump and in fact were straining their pumps, before cleaning 11,500 feet of 8-inch pipe they were delivering 415 gallons per minute, against a

BEFORE CLEANING

AFTER CLEANING

SHOWING RESULTS OBTAINED AT MT. VERNON, ILL., APRIL, 1911

Chart No. 1

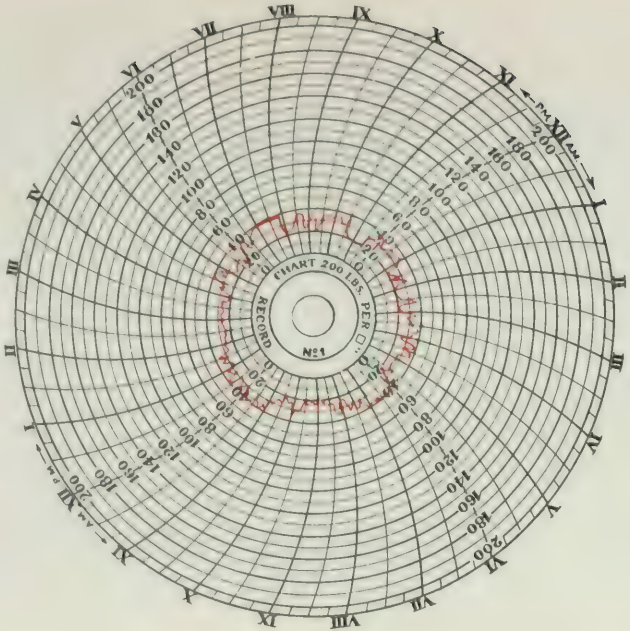
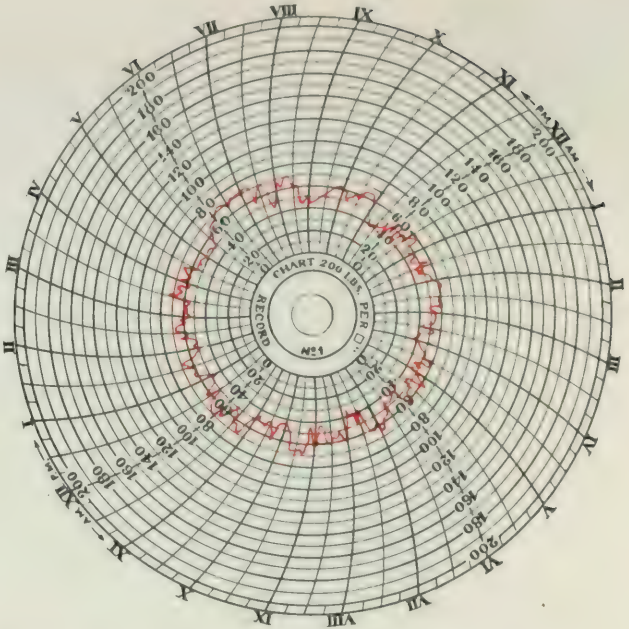


Chart No. 2



Recording Water Pressure Gauge Charts from Centralia, Illinois

Chart No. 1 shows the pressure maintained at the city hall, two miles from the pumping station, before the 12" force main was cleaned and chart No. 2 from the same gauge after cleaning. All conditions being the same, before and after cleaning. The pressure maintained at the pumping station was ninety pounds, in each instance. Reference—A. L. Reinhardt, superintendent of water works, Centralia, Illinois.

total head of 140 pounds, while after cleaning practically the same amount of water was pumped against a head of only 48 pounds. This was a private line owned by the Illinois Central Railroad, and while it was cleaned nearly a year ago, the water supply foreman in charge of this plant tells the writer that they are saving over 60 per cent on their fuel and in addition to this are saving $300 a year in repairs to the pumps, and in addition to affecting this great saving, they are pumping more water than they did before cleaning.

In Centralia, Illinois, there was a very marked increase in efficiency, which perhaps could not be credited to saving in operating expenses, unless by taking into account what it would cost to maintain the increased pressure without cleaning, but at the same time the results deserve to be mentioned here. Cuts herewith given show records of recording pressure gauge at the City Hall before and after cleaning. The same pressure was maintained at the pumping station before and after cleaning, but the average pressure maintained in the city was raised from approximately 30 pounds to an average of 60 pounds. I would also like to call your attention to the very marked example of saving as affected in Mt. Vernon, Illinois. In this city they were troubled with poor fire streams and with muddy water and also with high cost of pumping. They pumped by electrical power and before cleaning their force line and part of their distributing system they maintained at their city office 20 pounds pressure during the heavy draught hours, but to do this they were compelled to have 60 pounds at the pumping station. After cleaning with the same pressure at the pumping station, they had 45 pounds to 50 pounds at the city office, and they found they could cut down their average pressure at the pumping station 20 pounds and still maintain a better pressure at the city office than they had carried heretofore. Before cleaning they used 41.5 kilowatts to do their pumping, compared to 30 kilowatts after cleaning, a reduction of 27.7 per cent in power required to do their pumping. From this and many other examples which could be given, I believe that the economy of operation due to cleaning is fully proved.

3. THE USEFUL LIFE OF CAST-IRON PIPE AS AFFECTED BY CLEANING

Heretofore the life of cast iron water mains has been given as from eighty to one hundred years. Some authorities have claimed greater life and some shorter, but where pipes are affected by growth on the inside their useful life is very much less and in some cases is not over

twenty years, while the loss in iron is not great enough in most instances to make the actual life of the shell of the pipe anywhere near as short as one hundred years. Mr. Nicholas S. Hill, Jr., in his paper before this Association in 1907 gave an example of the amount of loss of iron due to corrosion inside of water mains at Washington, D. C., and showed that there was 3.5 per cent loss of iron by weight in thirty-five years. He further stated that this is not perhaps the total loss, as some of the remaining iron might be soft and useless. Also examination made upon the pipes which had been in the ground in Brooklyn for sixty years showed that the shell of the pipe was in very good condition. Some pittings were found on the interior and the corrosion was very bad, some of the tubercules being 2 inches in diameter and more, but the examination which was made by expert foundrymen, engineers and by the writer showed that the shell of the pipe was in excellent condition. In talking of the amount of iron which has been destroyed I have not mentioned the exterior of the pipe, but corrosion on the outside of water mains when laid under ordinary conditions is almost negligible when figuring the amount of iron destroyed. It is true that certain soils affect pipe badly and of course when laid in peat bogs or in cinders they are liable to be pitted on the outside, but these are extraordinary conditions and the actual shell of the pipe under ordinary conditions, I believe, is good for a great deal longer life than has heretofore been considered. There are pipes in this country today which have been in use for more than one hundred years, but the useful life of cast iron for water mains is often very short unless they are cleaned at the proper intervals. The length of these intervals depends entirely upon the local conditions for each different pipe, but from the experience thus far, I believe that cleaning will increase the useful life of cast iron pipe several fold.

4. INCREASE IN INVESTMENT DUE TO CLEANING WATER MAINS

As has been shown heretofore the pipe which is badly corroded does not have anywhere near the capacity of new pipe of the same diameter, and in figuring what the capacity is we find that a badly corroded large pipe often does not have the capacity of a much smaller clean pipe. Some examples of this are the tests made in Brooklyn. The 6-inch pipe before cleaning had a capacity equal to that of a $3\frac{1}{2}$-inch new pipe. This pipe was uncoated as it was laid in the days when present methods of coating were not known, but

after cleaning it had the capacity of a 5½-inch clean coated pipe. Also in the case of the 8-inch line tested in Brooklyn, the test showed that before cleaning it had the carrying capacity of a 4-inch new pipe, while after cleaning it had the capacity of a 7½-inch new coated pipe. Test No. 4 on a 12-inch main in Brooklyn showed that before cleaning it had a capacity of a 7-inch new coated pipe, while after cleaning it was equal to a 10-inch new coated pipe. These results indicate what can be done for uncoated pipe.

In the case of those which are coated take the test at Carbondale, Illinois, No. 29, where the pipe before cleaning had a carrying capacity equal to that of new 5-inch pipe, but after cleaning it had the full carrying capacity of an 8-inch pipe, and in almost every case where coated pipe is cleaned the full carrying capacity is restored.

These facts certainly indicate that where old distributing mains develop such large frictional losses their value is equal only to that of the smaller new pipe which would carry the same amount of water. The depreciation would then be the difference in value between the cost of the original pipe and the cost of the smaller pipe. As has been shown the carrying capacity can be restored by cleaning and, therefore, the value of the mains increased.

The writer has tried to show you by the introduction of these statistics that the greatest deterioration which water distributing systems suffer is from corrosion and deposit in the pipes. It is a clearly demonstrated fact that where this trouble exists it can be removed by cleaning, operating expenses reduced, the efficiency increased, the useful life of the pipe prolonged and the investment increased. The restoration of old distributing systems can be very effectively secured by cleaning.

DISCUSSION

Mr. Dunham: There are two features or points of interest in connection with such work that merit close attention.

One is the treatment to which the force main in question has been subjected during the period in which it filled up and became of little value. Was the water of uniformly good quality? Was the main thoroughly and frequently flushed out? Even good water becomes worse and more active in attacking some substances if it remains stagnant, organisms multiply, accumulations become more difficult to remove if allowed to remain a long time. Opening a hydrant or two for even a small main effects very little improvement. To set

forth the actual facts with respect to the treatment any badly incrusted main has received would be of great value to superintendents.

The second point of particular interest may be broadly covered by a published statement from high authority to the effect that after cleaning corrosion goes on much more rapidly, so that the oftener a pipe is cleaned the shorter the period of use without cleaning. No one should be better informed respecting this phase of the subject than the parties engaged in prosecuting the work. Making a test upon the completion of a contract does not interfere with making subsequent tests. If the value of the work performed can be determined by later tests all parties should be interested to see that such tests were carried out in the fairest manner.

MR. HODGMAN: I can not give any definite answer to that question. The same question has been put by the author to several superintendents and engineers for whom pipe has been cleaned and they have stated that the incrustation did not grow any faster after cleaning than it had before cleaning. I tested pipe in Little Rock, Arkansas, three years after it had been cleaned, and found it was carrying 155 per cent more water than it had carried before it was originally cleaned, that is, it had a carrying capacity of 74 per cent of that of new pipe three years after cleaning, while before it was originally cleaned, it had only 29 per cent or 30 per cent of the carrying capacity of a new pipe. I do not believe, however, from observations that I have made, that under ordinary conditions the rusting takes place any more rapidly after cleaning mains than it does in new pipe.

MR. CHESTER: Wouldn't there be more tuberculation if you removed a large percentage of the coating in the cleaning?

MR. HODGMAN: Undoubtedly there would be more tuberculation if a large proportion of the coating were removed in the cleaning, but from observations which I have made after cleaning, the coating has not been removed although in some instances the original imperfection of the coating allowed the water to act directly upon the pipe and when the tuberculation was removed the poor coating came with it.

I quote herewith from a letter received from Chas. R. Bettes, Chief Engineer, Queens County Water Company, Far Rockaway, N. Y., which is similar to many others which have been received covering the same lines.

Replying to your favor of April 20, 1909, asking our experience as to the result of cleaning pipe.

We have had occasion to cut out sections of the 12 inch, 8 inch and 6 inch pipe after it was cleaned and in no case have we found the coating destroyed or injured. For the first few days after cleaning there may be some discoloration in different parts of the system, but this is easily remedied by flushing the mains. Except as above mentioned there has been no discoloration from cleaning.

We have noticed that so far there is no deposit in pipe cleaned three years ago and are satisfied that the cleaning does not injuriously affect the quality of the water.

MR. CHESTER: In that tabulation of results obtained by the cleaning of old water mains in various localities in the United States, do Nos. 6, 7, and 8 refer to Huntington, West Virginia? Have you made any tests or have you any results with you as to any tests made there.

MR. HODGMAN: I have not.

MR. HODGKINS: The supposition is that the coating protects the pipe. I would like to know as to the age of pipe when cleaning becomes advisable. Do I understand that cleaning destroys whatever coating there might be there? In that case it might be the greatest error to clean too early. I should like to know the length of time that should elapse before cleaning the pipe.

MR. HODGMAN: In regard to the length of time before they should be cleaned, that differs for every different water, and even with the same kind of water with different castings of pipe. There are some stations around the Great Lakes where they have had very little incrustation after eighteen or twenty years; and I do not know of any where they have had very serious results short of that time. I know of other than lake waters, more particularly surface waters, that have affected pipe very seriously inside of six or eight years; so that it is hard to give any definite answer to that; but I can say very positively that where the coating is intact under the tuberculation that cleaning does not injure it.

MR. HOPKINS: There are three things which it seems to me it would be interesting to know in connection with this paper; one is the length of time that the pipe in each one of these cases had been laid; second, an analysis of the water pumped or that flowed through the pipe, third, the source of supply, whether ground water, surface water,

or lake water, or what. Such data it seems to me would be of great value. I do not know that the author of the paper can give us that off-hand, but if he can supply it later in connection with the publication of the paper, it would be desirable.

MR. HODGMAN: No doubt data can be given as to the source of supply. As to this analysis I would refer Mr. Hodgkins to the paper read by Mr. Nicholas S. Hill, Jr., before this Association in 1907 on the subject, "Tuberculation and the Flow of Water in Mains." I doubt very much, however, if the age of the pipe can be given in a large number of the cases mentioned in the tables connected with this paper, because a great deal of the work was done for municipalities and several of them have no records to show when the pipe was laid.

MR. CHESTER: Municipalities keep no records of pipe laying, is that it?

MR. HODGMAN: I have known some that did not.

MR. MCMILLAN: We consider our records fairly good although we are municipal. We had a new connection to make to the water tower about two years ago, and removed some pipe that had been in place there for thirty-five years. We found that the original tar coating was still inside of the pipe; it was in such good condition that the pipe taken out was put back in place and considered as good as new. There was no corrosion and no accumulation of any foreign matter in the pipe. It had not been cleaned by any mechanical means. The source of supply is Lake Michigan. So that this paper would only apply to certain localities as to the condition of the water, etc.

MR. WORRELL: We have just finished cleaning about 11,000 feet of 16-inch conduit at Meridian, Miss. I was constantly on the work, because I was very much interested in getting results. My observation made very carefully and closely was that the coating of the pipe was not destroyed at all except by taking off the little nodules of rust that adhered to the pipe itself; and the results obtained on that work showed about 100 per cent increase in the carrying capacity of the pipe. It is used as a conduit to bring water from the reservoir, and the reservoir is supplied by springs. By the way, that answers the gentleman's questions as to the kind of water. It works under a head of about 8 pounds but unfortunately for the records we have not had a test since January 11, 1910. That pipe was then carrying

slightly less than 46,000 gallons an hour. Of course some incrustation has occurred during that period. The last test was made on Sunday a week ago and showed that the pipe was delivering 92,000 gallons an hour.

MR. CHESTER: What was the condition of the head?

MR. WORRELL: The records are as good, though more favorable to the head carried in January, 1910, because we have more water in the plant and have more water in the reservoir in January than in May as a rule.

MR. CHESTER: It seems to me that you have less head at the other end.

MR. WORRELL: We made an allowance for that.

MR. CHESTER: You have a possible variation of something like 30 or 40 feet head?

MR. WORRELL: Not that much; it is possible to have about 28 feet. We did not find it necessary to use booster pumps after the conduit was cleaned. We shut down two booster pumps at a saving of about $250 per month.

MR. CHESTER: What was the character of the scale you took out?

MR. WORRELL: Such as is usually found in that kind of pipe. We have not had it analyzed. It is in the hands of a chemist for analysis now.

MR. CHESTER: You did not find your water was bad for boiler use?

MR. WORRELL: No, sir, not very bad.

MR. DUNHAM: If it can be obtained I would like to have some idea as to the amount of attention that was given to these mains before it was decided to clean them; how often they were flushed, and to what extent they were flushed, and how they were treated in general. That would be interesting, I think.

MR. HODGMAN: In reply to Mr. Dunham's question regarding the attention given to pipes, I would say that from observations made regarding the efficiency of water mains which have been frequently

flushed, they are no better than those that are unflushed except where there is a collection of mud only in the pipes. Flushing will undoubtedly remove most of the sediment except where it has been allowed to gather for a long time before any flushing is done. There is one plant with which the author is familiar which is owned by a private corporation where flushing is carried on with great regularity, but they are seriously troubled not only with dirty water, but with corrosion and it would seem that where a great deal of flushing is done that there is a tendency toward greater corrosion.

Mr. W. Z. Smith: With reference to the cleaning of the 30-inch main in Atlanta, mentioned by Mr. Hodgman in his paper. At the time this main was cleaned, I was not in charge of the water department; although connected with it. The main referred to is a force main, about 18,500 feet in length from the river pumping station to the storage reservoir. On account of considerable tubercular growth, it was found necessary to have this main cleaned. This for a time gave relief, but within a few years, on account of lack of capacity, we had to put in another main. Referring to the suggestion by Mr. Dunham, I will state that the flow of water through these mains is constant, but I do not know the condition of the 30-inch main at the present time, as we have made no examination of it within the last few years. I will state for the information of the gentlemen present that we find that the corrosion or incrustation occurs in the pipes in the city, which carry nothing but filtered water, as well as in the mains that carry raw water. We very recently cut into a 16-inch main, and found it in as bad or worse condition than was the 30-inch main referred to by Mr. Hodgman. We find also that in some of the mains, which have been in the ground a much longer time than the 16-inch main, which we cut into recently, there is practically no corrosion.

It is a condition that seems to exist in parts of the city, where the flow of water is not so rapid. I do not know how to account for it other than from the fact that in slow moving bodies of water, the chemicals have more opportunity to operate, thereby setting up a tubercular growth.

Mr. Hodgman: I would like to ask Mr. Smith if it is not a fact that those pipes which are affected the worst are the ones which carry the most water, or in other words under ordinary conditions have a higher velocity in them.

MR. W. Z. SMITH: In the case of the mains within the city I think that is the case; but the other main had a constant pumpage through it. The 30-inch main was carrying raw river water and had a constant flow delivering over 11,000,000 gallons, which was increased according to the record to 17,000,000 gallons.

MR. WEHR: As a further illustration that the character of the water is the leading element in the incrustation of the pipe, I might cite an instance in our plant where in 1907 we took up about 12,000 feet of 10-inch pipe and about 5,000 feet of 12-inch pipe which had been in service from the pumping station in an outlying district. This pipe had been down for twenty-one years. We hauled this pipe ten miles across country and relaid it. Before laying it we thought it might be well to scrape it out. It felt smooth, but we ran the brushes through it and did not get out enough to pay for the time spent in cleaning, so we did not stop to complete the cleaning, we simply relaid it as it was. I apprehend that we will not have to consult a Pipe Cleaning Company during my administration at least.

DISCUSSION

PRESIDENT ALVORD: The first thing which we will take up this morning, gentlemen, is some discussion of the matter presented last evening. Perhaps it will be desirable if you hear first from Mr. Maury a few words on some phases of the Canal which may have occurred to him since last evening. Then if any questions arise in the minds of any of you which you would like to ask him, I presume he would be very glad to answer. I am not inferring that Mr. Maury forgot anything last night, but thought merely that he might possibly have something to add.

MR. MAURY: Gentlemen, I will be very glad to answer any questions that I can. I am afraid I could not answer any very technical questions; but for the sake of the enterprise down there and in line with that feeling of patriotism and pride in that great undertaking which we all ought to have, I am glad to add one or two little things that I did not mention last night.

As to the economy with which the work is being done on the Canal Zone: Just before leaving for Panama I signed a contract for some steel work f.o.b. cars, Peoria, amounting to something less than 100,000 pounds, and it cost me $5\frac{1}{4}$ cents per pound f.o.b. cars, Peoria. The

first thing I saw in the Canal Record was the statement that a contract had been let for some $6,500,000 worth of steel for lock-gates. That steel delivered and erected in place was bought for $3.785 per cwt. The same steel delivered, not erected, was $2.62. The steel that I got at Peoria included about 1 cent more cost for fabrication. So that I was paying about $4.25 in Peoria for what the Canal Commission was buying for $2.62, in Panama the only other difference being in the magnitude of the contract.

Again, the cost of dry excavation in 1910, was 67 cents per cubic yard. That was for excavation in the dry, 70 per cent of the yardage being solid rock requiring drilling and blasting, and the average haul being about twelve miles. The 67 cents included all overhead and administration charges except the Civil and Sanitary Administration costs in the Canal Zone, and large allowances for depreciation on plant. Such of us as have to excavate rock and dirt and haul it twelve miles must realize, no matter how large the job may be, that at such a figure the work is being done cheaply.

In reference to the time of the completion of the Canal, you may remember that the date was set at January 1, 1916, and later on, some eight or ten months ago, it was said that the Canal would be formally opened on January 1, 1915. Colonel Goethals in his talk to us the last evening we were there announced that the locks and dams would be finished in all reasonable probability on the first of June, 1913, that the Culebra cut would be navigable for boats of 26 feet draft on the first of September, 1913, and that they would then informally open the Canal and proceed to operate it for ships of that draft and under, taking out such slides as came in, with dredges; that they would continue the Canal in operation, informally, until the formal opening on January 1, 1915, as advertised.

I believe I did not tell you last night much in regard to the sanitation of the Isthmus. We could not fail to be impressed with that as one of the most important factors in rendering possible all these admirable results. One who goes to the Isthmus and sees the efficient manner in which they keep the right of way cleared, and vegetation cut down; and observes the trenches with little cans of kerosene at the top of each little trench, each can dropping one drop every ten seconds sees the abundant precautions taken in every direction, and the result that follows in the absence of mosquitoes and the practical absence of flies and the remarkably low death rate in the Zone; cannot fail to realize that the sanitation as it has been carried on there under Colonel Gorgas is beyond all words of praise.

SOME FUNDAMENTAL CONSIDERATIONS IN THE DETERMINATION OF A REASONABLE RETURN FOR PUBLIC FIRE HYDRANT SERVICE

By Metcalf, Kuichling and Hawley[1]

The income of a water works corporation is usually derived from the performance of two distinct services; first, the supply of water for public fire protection service; second, the general supply of water for domestic, industrial, and public uses. The sum of the receipts from these two sources should be sufficient to place the corporation on a sound financial basis within a few years after the completion of the works, or after about two-thirds of the population of the community have become permanent consumers.

The basis for the determination of the reasonable or legitimate return for public hydrant or fire protection service has, so far as the writers are aware, never been outlined or passed upon judicially by our courts in such a manner as to be of general applicability.

Not only has intelligent discussion of this subject been neglected, but commercial considerations and off-setting allowances for public franchise, or the right to build and operate water works, have too often controlled, and have made the actual resulting payments for hydrant rental of little value from a theoretical standpoint; without relation to the cost of the service rendered, and therefore of little significance in a consideration of the cost or value of public fire protection service.

As is well known to water works operators, one of the two following considerations has usually controlled in the negotiations leading to the establishment of water works; first, what might be termed the "method of averages"—that the hydrant rental and water rates should not exceed the average rates paid in the surrounding district or state, or perhaps in the nearest large city—which has found application in the larger communities; and second, what might be termed the "guaranty basis"—that the hydrant rental should be substantially equal to the interest charges upon the neces-

[1] Leonard Metcalf, Emil Kuichling, William C. Hawley.

sary investment, leaving the water rates to meet operating, maintenance, and depreciation charges and profit—which, has found application in the towns and smaller cities. In the early history of water works development therefore, the demand for water service has controlled rather than any equitable consideration of the cost or value of the service rendered.

This paper outlines a rational mode of determining how much income should be derived yearly from the general public fire protection service rendered by the works through the public fire hydrants, and does not consider the value of the kindred service rendered by supplying water to special apparatus for extinguishing fire that may be placed in public or private buildings such as private hydrants or standpipes, sprinklers, or other automatic devices. It is assumed that the quantity of water and extra capacity of distributing pipes required for the public hydrant service is always somewhat greater than that which is needed for the special apparatus referred to, when it is brought into action. It has been generally claimed that the yearly cost of this extra capacity for fire protection should be borne by the community as a unit, and when this principle applies, no large additional revenue for special fire protection service can be expected.

In support of this principle, it is claimed by the makers of special automatic apparatus for extinguishing fire that a discharge of from 750 to 1000 gallons of water per minute for a period of 10 to 15 minutes, has been found by long experience sufficient to overcome most incipient fires in mercantile and factory buildings, whereas, from two to ten times this rate of discharge is usually required to extinguish a fire in such a building after it has got beyond the control of the special apparatus and requires the attention of the public fire department. It may also be said that the capacity for fire hydrant service in even the smallest industrial community should not be less than 1200 gallons per minute, and should increase in some ratio with the population.

DATA REGARDING FIRE HYDRANT SERVICE IN VARIOUS CITIES IN THE UNITED STATES

In Table I following, are shown certain fundamental data relating to fire hydrant service in various cities of the United States, which are regrouped from a pamphlet upon "Tabulation of Water Rates of Various Cities of the United States, also Data regarding Fire

Hydrants,"[1] compiled for the Indianapolis Water Company, August 1909, by Messrs. Frank C. Jordan, Secretary, and Charles C. Crey, Purchasing Agent of this company, with additions by the writers, of population data based upon the U. S. Census returns.

TABLE I

Hydrant Rentals in United States, 1908

(Works owned by corporation not by the municipality)

PLACE	POPULATION 1910	SYSTEM OF SUPPLY	RENTAL PER HYDRANT PER YEAR
Over $50 per Hydrant			
Ashland, Wis.	11,594	Direct	$61 25
Belleville, Ill	21,122	Direct	75.00–60 00
Beloit, Wis	15,125	Direct	60.60–40.00
Birmingham, Ala	132,685	Reservoir and Direct	55.00
Brainard, Minn	8,526	Direct	66.10
Columbus, Ga	20,554	Standpipe	80.00–40.00
Council Bluffs, Ia	29,292	Reservoir	60.00
Denison, Texas	13,632	Standpipe	79.25
Elkhart, Ind	19,282	Direct	59.00
El Paso, Texas	39,279	Direct	52.00
Elwood, Ind	11,028	Direct	60.00
Iron Mountain, Mich	9,216	Reservoir	58.00
Ironwood, Mich	12,821	Standpipe	75 00–50.00
Manitowoc, Wis	13,027	Standpipe and Direct	65.00–40.00
Mexico, Mo	5,939	Direct	55.00–50.00
Moberly, Mo	10,923	Direct	84.00
New Albany, Ind	20,629	Reservoir	60.00–50.00
New Orleans, La	339,075	Direct	60.00–45.00
Oconto, Wis	5,629	Reservoir	65.00–60.00
Omaha, Neb	124,096	Direct and Reservoir	60.00
Richmond, Ind	22,324	Reservoir	55.00–49.00
Winfield, Kas	6,700	Reservoir	57.00
Average (22 places)			$59.94
$40 to $50 per Hydrant (inclusive)			
Adrian, Mich	10,763	Reservoir	$50 00
Akron, Ohio	69,067	Direct	40 00
Anniston, Ala	12,794	Reservoir	50.00
Ann Arbor, Mich.	14 817	Reservoir	45.00–40 00
Alton, Ill	17,528	Standpipe	40,00
Atchison, Ka	16,429	Reservoir	40 00
Baton Rouge, La	14,897	Reservoir	50 00

[1]Reprinted in Volume 24, No. 4, December, 1910, *Journal of the New England Water Works Association*.

TABLE I—Continued

PLACE	POPULATION 1910	SYSTEM OF SUPPLY	RENTAL PER HYDRANT PER YEAR
$40 to $50 per Hydrant (inclusive) continued			
Bucyrus, O.	8,122	Direct	40.00
Burlington, Ia.	24,324	Direct	45.00
Butte, Mont.	39,165	Reservoir	50.00
Charleston, W. Va.	22,996	Direct	50.00
Chester, Pa.	38,537	Reservoir	40.00
Creston, Ia.	6,924	Standpipe	50.00
Danville, Ill.	27,871	Direct	40.00
Durham, N. C.	18,241	Reservoir	50.00–40.00
Eau Claire, Wis.	18,310	Direct	54.00–44.00
Freeport, Ill.	17,567	Standpipe	50.00
Fort Madison, Ia.	8,900	Reservoir and Direct	40.00
Franklin, Ind.	4,502	Standpipe	40.00
Gadsden, Ala.	10,551	Reservoir	46.16
Hagerstown, Md.	16,507	Reservoir	45.00
Huntington, W. Va.	31,161	Reservoir	40.00
Indianapolis, Ind.	233,650	Direct	45.00
Iowa City, Ia.	10,091	Direct	45.00–50.00
Keokuk, Ia.	14,008	Direct	50.00
Knoxville, Tenn.	36,346	Reservoir and Standpipe	40.00–45.00
Leavenworth, Ka.	19,363	Direct and Reservoir	40.00
Lexington, Ky.	35,099	Direct	50.00
Linton, Ind.	5,906	Direct	50.00
Little Rock, Ark.	45,941	Gravity	50.00
Louisiana, Mo.	4,454	Reservoir	50.00–33.00
Milford, Mass.	13,055	Direct	50.00
Newark, Ohio.	25,404	Reservoir	48.00–45.00
Oskaloosa, Ia.	9,463	Direct and Standpipe	50.00
Owensboro, Ia.	16,011	Direct	50.00–40.00
Ottumwa, Ia.	22,012	Reservoir	42.00
Pensacola, Fla.	22,982	Standpipe	60.00–40.00
Pine Bluffs, Ark.	15,102	Direct	43.00–40.00
Pittsburg, Kas.	14,755	Tank	46.00–45.00
Rensselaer, N. Y.	10,711	Standpipe	40.00
St. Joseph, Mo.	77,403	Reservoir	40.00
Seymour, Ind.	6,305	Standpipe	40.00
Shreveport, La.	28,015	Direct	50.00–40.00
Springfield, Mo.	35,201	Standpipe	40.00
Streator, Ill.	14,253	Direct	45.00–35.00
Superior, Wis.	40,384	Direct	40.00
Uhrichsville, O.	4,751	Reservoir	40.00
Valparaiso, Ind.	6,987	Direct	50.00
Washington, Pa.	18,778	Reservoir	40.00
Wilmington, N. C.	25,748	Standpipe	50.00
Winchester, Ky.	7,156	Direct and Standpipe	40.00
Average (51 places)			$44.60

TABLE I—Continued

PLACE	POPULATION 1910	SYSTEM OF SUPPLY	RENTAL PER HYDRANT PER YEAR
$30 to $39 per Hydrant (inclusive)			
Chillicothe, Mo	6,265	Direct	$39.50
Clinton, Ia	25,517	Direct	30.00
Cortland, N. Y.	11,504	Standpipe	33.33
Davenport, Ia.	43,028	Direct	38.00
Defiance, O.	7,327	Standpipe	40.00–35.00
Denver, Col.	213,381	Gravity and Pumps	25.00–35.00
Eureka, Col.		Standpipe	37.50
Green Bay, Wis	25,236	Reservoir	37.50
Greensburg, Ind	5,420	Direct	33.00
Greenville, S. C	15,741	Reservoir	40.00–30.00
Hopkinsville, Ky	9,419	Standpipe	40.00–30.00
Lincoln, Ill	10,892	Standpipe and Direct	35.00
Macon, Ga	40,665	Gravity	40.00–37.50
Mt. Vernon, Ind	5,563	Direct and Reservoir	37.50
Nashua, N. H	26,005	Reservoir and Direct	30.00
Newport, R. I.	27,149	Reservoir	35.00
Noblesville, Ind	5,073	Reservoir	33.33
Ogden, Utah	25,580	Reservoir	35.00
Oskosh, Wis	33,062	Direct	40.00–25.00
Paterson, N. J.	125,600	Direct and Standpipe	30.00
Peoria, Ill.	66,950	Reservoir and Direct	41.60–25.00
Quincy, Ill	36,587	Reservoir	45.00–20.00
Raleigh, N. C	19,218	Standpipe and Direct	32.50
Sedalia, Mo.	17,822	Direct	30.00
Sharon, Pa.	15,270	Direct	35.00
Shelbyville, Ind	9,500	Direct	30.00
Southbridge, Mass	12,592	Gravity	30.00
Tampa, Fla	38,254	Standpipe	35.00
Texarkana, Ark	5,655	Direct	30.00
Vincennes, Ind	14,895	Standpipe	33.33–40.00
Wabash, Ind	8,687	Standpipe and Direct	38.00
Warren, Ohio	11,081	Standpipe	45.00–25.00
Washington, Ind	7,854	Reservoir	35.00
Waterloo, Ind.	26,693	Direct and Standpipe	35.00
Average (34 places)			$34.16

TABLE I—Continued

PLACE	POPULATION 1910	SYSTEM OF SUPPLY	RENTAL PER HYDRANT PER YEAR
$20 to $29 per Hydrant (inclusive)			
Bristol, Conn.	9,527	Reservoir	$20.00
E. Providence, R. I.	15,808	Direct and Standpipe	20.00
Greenwich, Conn.	3,886	Gravity	25.00
Johnstown, Pa.	55,482	Gravity	25.00
Joplin, Mo.	32,073	Direct	22.50
Kokomo, Ind.	17,010	Direct	25.00
Long Branch, N. J.	13,298	Direct	25.00
Newport News, Va.	20,205	Standpipe	25.00
Norwich, Conn.	20,367	Reservoir	40.00-15.00
Oneonta, N. Y.	9,491	Reservoir	25.00
Paducah, Ky.	22,760	Standpipe	28.50
Roanoke, Va.	34,874	Direct	20.00
So. Bethlehem, Pa.	439	Reservoir	25.00
Average (13 places)			$24.12
Less than $20 per Hydrant			
Bridgeport, Conn.	102,054	Reservoir	$12.50
Plainfield, N. J.	20,550	Standpipe	15.00
San José, Cal.	28,946	Direct	6.00
Stockton, Cal.	23,253	Direct	12.00
Sunbury, Pa.	13,770	Direct	18.00
Average (5 places)			$12.70
Average of total (125 places)			$41.05

NOTE: It will be noted that the returns for certain towns give two different hydrant rates. In such cases in default of information as to the exact average hydrant rental, a mean value of the two figures quoted has been assumed in making up the general averages.

A grouping of the hydrant rentals, contained in Table I, according to localities, gives the following interesting results:

TABLE II

Average of 22 cities in Eastern States	$29.38
Average of 73 cities in Central and Southwestern States	45.03
Average of 24 cities in Southern States	42.54
Average of 6 cities in Western States	28.42
Approximate average of total number	$41.05

It is also of interest to note that the average of all (103 cities), excepting the Eastern cities, is $43.48, approximately 50 per cent greater than for the Eastern States. It is well to note, however,

that the average for the Eastern States is obtained from the record of but 15 cities supplied by private works.

HYDRANT RENTALS BY DECADES

In order to ascertain if there was ground for the belief that hydrant rentals had decreased somewhat in the last two or three decades, the authors sent out the following reply postal cards to the list of privately owned (corporation) water works, shown in Table I.

Boston, Mass., February 2, 1911.

My dear Sir: -

I am trying to gather some comparative information concerning the annual rental paid per hydrant in various cities, in the years 1880, 1900, and 1910, for use in an article upon "Hydrant Rentals," being prepared by Mr. Emil Kuichling, Mr. William C. Hawley, and myself, for presentation before the American Water Works Association at its coming convention to be held in Rochester, N. Y. In this article we propose not only to give some comparative facts concerning actual hydrant rentals paid in this country, but also to discuss different points of view relating to what constitutes a reasonable hydrant rental.

Will you be good enough to co-operate with us to the extent of answering the questions contained upon the attached reply postal card? The rental per hydrant is the most important information desired.

Leonard Metcalf.

REPLY CARD

Date.....

Name of City.....State.....

Date	No. of Hydrants.	Rate per Hydrant (public)
1880		$
1890		
1900		
1910		

Did the hydrant rental cover water for other public uses? Is any direct tax paid upon franchise independent of the general tax levied?

Signature.....

The results obtained by this inquiry were somewhat discouraging and of a negative character, as will be seen by the following summary:

One hundred and forty cards were sent out from which 81 or 57.8 per cent of replies were received. Of this number of replies 35 per cent showed a slight reduction in the basis of hydrant rental charge in the year 1910 as compared with the years 1880, 1890 or 1900. In a number of other places there was also a trivial reduction in rental paid per hydrant, resulting from the fact that under the terms of the contract a smaller rate per hydrant was to be paid

for all additional hydrants in excess of a certain specific limited number. Three cases showed an actual increase in hydrant rentals.

The average hydrant rental in 55 places in the year 1910 amounted to approximately $35.03, as against $39.39 in the year 1900. Similarly, the average rental in 12 places amounted to $30.25 in the year 1910, as compared with $44.05 in the year 1880.

While the replies received are too limited to draw final conclusions from, they indicate that no substantial reduction has taken place in rates paid for hydrant rental, during the past thirty years. It should also be added that in the great majority of cases, the hydrant rental covered the furnishing of water for other public uses, tending to make the data incomparable.

POSITION OF RAILROAD COMMISSION OF WISCONSIN

In view of the fact that the revenue derived from public fire protection service is rarely commensurate with the cost of the service in water works properties in the United States, as will be shown hereafter, it is refreshing to note the frank and fair way in which the Railroad Commission of Wisconsin has approached this problem in rating as evidenced by certain of its reports.

Thus, in its Report No. U.-52 upon the Ashland Water Company, dated November 1, 1909, p. 292, it says:

> It requires no demonstration to show that a large part of a water plant in every town where the city is a user, is simply held in readiness for the purpose of fire protection. It may not be called into use very often, yet the investment is there and is held in constant readiness.
>
> In the Appleton Water Works case, engineers and experts estimated that the cost of constructing that plant would have been reduced by from 40 to 50 per cent if the plant so constructed had been designed only for domestic use. A large part of the equipment is necessary, whether the plant is to be used only for domestic purposes or for both public and domestic service. Where a plant is actually in operation, and large portions of the equipment are used in common for domestic and public consumption, a separation of the investment shows a larger percentage to be devoted to municipal use than in the above mentioned estimates. The engineer of the Commission has made a detailed separation of properties devoted to municipal and domestic service, respectively.

After giving in detail the methods used by the Commission's engineer in apportioning the values of the physical property devoted first, to the public service, and second, to domestic and industrial service, the Commission continues, p. 295:

The separation thus made shows that 54.5 per cent of the plant at Ashland is made necessary to satisfy the demands of the city. It follows that 54.5 per cent of the capacity, or fixed cost of service, should be charged to the city to cover the cost of furnishing water to schools, fountains, other public buildings, for flushing, and for fires.

For the operating expense probably no better basis of apportionment can be determined than the consumption by various classes of users.

(P. 297) In other words, private water consumers have borne a part of the burden which properly should be borne by the tax payers. The entire community derives the benefit from adequate fire protection, and the cost of this protection should be pro-rated on the entire tax-paying population. In this respect the present rate schedule can hardly be said to be equitable.

Whatever the exact amount may be, however, which in equity should be added to the city's share of the cost of the service according to the present distribution of revenues, the total charges upon private consumers will be reduced by just that amount.

In Report No. U.-74 upon the Jefferson Municipal Electric Light and Water Plant, dated August 30, 1910, the Commission says, p. 577:

In order that a just and fair distribution of the total expense of the plant between the city and private or domestic consumers shall be made, it is necessary to consider the functions of the plant in this particular city. The general functions of a water works have been quite clearly set forth in Turneaure and Russell's work on "Public Water Supply," wherein it is stated:

"The functions performed by water works are: (1) To furnish water for private use; (2) To furnish water for public use on streets and for sewers, fountains, public buildings, etc.; and (3) To furnish fire protection to property. In (1) and (2) the cost of service may be considered approximately proportional to the quantity of water supplied, but in (3) it is out of all proportion to the amount of water used, for while the cost of construction is greatly affected, the total amount of water consumed is slight. The extra cost in furnishing fire protection is due to largely increased pumping capacity, increased size of mains, services or stand pipe, cost of hydrants and increased cost of maintenance."

The Commission has discussed this feature of the functions of a water works in several earlier decisions:

"It requires no demonstration to show that a large part of the water plant in every town, where the city is a user, is simply held in readiness for the purpose of fire protection. It may not be called into use very often, yet the investment is there and is held in constant readiness." City of Ashland v. Ashland Water Co. 4 W. R. C. R. 273, 292; City of Ripon v. Ripon Light & Water Co. 5 W. R. C. R. 166.

The methods employed by the Commission's engineer in making the determination of that part of the plant or investment necessary for public use have been outlined in the above mentioned decisions.

The proportion of the investment necessary for the public service may vary somewhat, depending upon the local conditions. It has been held by en-

gineers and water works men whose experience and study of the question make their opinions of weight that this proportion will but seldom, if ever, go below 50 per cent of the total cost of the plant and system. In those cases where the Commission has investigated the matter in detail and has made a separation between public and private or domestic use, the proportion of total investment chargeable to public use has been found to greatly exceed 50 per cent. An examination of the particular conditions under which the Jefferson water works operates, has been made. A separation of the total investment between public and domestic or private use, based on the same methods as outlined in previous decisions, shows that in this case 75 per cent or more of the total investment has been made necessary for fire protection and other public purposes. Since 75 per cent of the investment is necessary for public use, it follows that upon any equitable basis of rate determination the city should pay 75 per cent of the fixed or capacity expenses. This amount would be $2,481.85, and is the city's share of the capacity expenses (total $3,309.14).

The output expenses must be distributed between the public and private users on the basis of the amount of water consumed by the two classes. The output costs are directly proportional to the amount of water supplied to the classes of consumers.

"Cities are . . . . as a rule, large users of water. Streets must be sprinkled, sewers flushed, schools and other public buildings must be supplied with water. In fact, the city alone often uses as much or more water than the private consumers combined. These facts must be considered in determining and distributing the charges for water. In re Appl. Madison City Water Works, 3 W. R. C. R. 299, 319."

Further reference is also made to this subject in the reports of this Commission in its decision upon the Ripon Light and Water Company case, copies of which were not, however, available to the authors.

COMMON METHOD FOR PAYING FOR FIRE PROTECTION SERVICE

The usual method of paying for public fire protection service is by an annual rental per hydrant, coupled with the requirement in the contract of the water company with the community served, that one additional hydrant shall be ordered in the case of extension of the pipe system for every 600 feet, more or less, of such extension.

It is believed that this method of charge is a less equitable one than would be *the payment of a lump sum for public hydrant service, granting to the city the right to attach as many hydrants as it may desire to the water mains of the company, upon the additional payment of the actual cost of such additional hydrants and connections; and making provision for the increase of this annual payment for hydrant service, upon some such basis of payment as pro rata increase in population, or assessed*

valuation, or pipe line mileage within the municipality or district served by the water works.

In this connection, it is interesting to note the standard recently adopted by a water company supplying a number of different municipalities which was as follows:

PERIOD OF CONTRACT.	ANNUAL CHARGE FOR FIRE PROTECTION SERVICE.	
	Per Mile of Distribution Pipe System.	Per Fire Hydrant in Service.
1 year	$325	$15
10 years	275	6
20 years	260	5

It will be noted that in this case, the charge for fire protection service is a combination of a mileage charge and an annual charge per hydrant, the latter being designed to cover the approximate maintenance and fixed charges resulting from the installation of additional hydrants.

BASES FOR ANALYSIS OF HYDRANT RENTAL CHARGE

Obviously the equitable hydrant rental should lie at some point between the cost of the service to the water company and its value to the community. The value of the public fire protection service must be greater than its cost, otherwise there will be no demand for it and no hydrant rental question.

The reasonableness of the charge for hydrant rental may be reviewed from fivepoints of view:

1. The cost of furnishing fire protection service.

2. The value of this service to the community, as measured by the saving in fire insurance premiums, ignoring the effect of the economic waste resulting from loss in business, income and wages, in the reconstruction period following the fire, and the loss of property that cannot be replaced.

3. The actual and desirable number of hydrants and distance between them and the annual rental per hydrant resulting from the assumption of certain gross annual payments for fire protection service.

4. The effect upon taxes, based upon the assessed valuation of property in the municipality or district served, and different assumed annual charges for fire protection service.

5. The relative cost of different kinds of public service,—police and public safety, light, and fire protection,—in the community served.

COST OF FURNISHING FIRE PROTECTION SERVICE

It has been assumed, perhaps generally, by engineers, that of the entire cost of water works that furnish public fire protection as well as domestic and industrial service, approximately one-half is involved by the cost of the fire protection service. While this may be the case in large towns or small cities, it is not believed by the writers to be a safe or true statement as applied to the water works generally, regardless of the extent of population in the communities served.

It is believed that a fairer statement of the true conditions would be, to say that *the cost of the portion of the water works plant involved by fire protection service, probably constitutes from 60 per cent to 80 per cent of the entire cost of the physical property in the case of communities having less than 5000 population, 20 per cent to 30 per cent in communities of 100,000 population, more or less, and perhaps 10 per cent to 20 per cent in the case of our largest cities.* Whatever the exact figures corresponding to average conditions in the United States may prove to be hereafter, when all of the facts have been determined, if such a time shall ever come, it is safe to say that the figures cited above probably indicate the general conditions very much more closely than do the prevailing opinions as first cited.

As evidence bearing upon the cost of public fire protection service, the following analysis is submitted.

PER CENT OF TOTAL CARRYING CAPACITY OF WATER PIPING SYSTEM, CHARGEABLE TO FIRE PROTECTION SERVICE

From time to time during the past twenty years, standards for the amount of water required for fire protection service, have been suggested by different engineers.

Upon diagram No. 1 is shown the quantity of water, in million gallons per day, required for domestic, industrial, and public uses, excluding fire protection demands, and the quantity of water required for fire protection only, under the standards suggested by Mr. John R. Freeman (1892), Mr. Allen Hazen, Mr. Emil Kuichling (1897), and the National Board of Fire Underwriters (1910), as interpreted by the writers.

Mr. Freeman suggested two standards—a maximum and a minimum—the first of which only is shown on this diagram, for the sake of

simplicity and as being the more important to-day. A full discussion of Freeman's standard will be found in the *Journal of the New England Water Works Association* for the year 1892, Vol. VII, p. 49. The formulae for Freeman's curves, as worked out by Mr. Kuichling, are as follows:

Y minimum $= 1.7 + X + 0.03\ X$ where Y = the number of fire streams

Y maximum $= \frac{X}{5} + 10$ and X = the number of thousands of inhabitants.

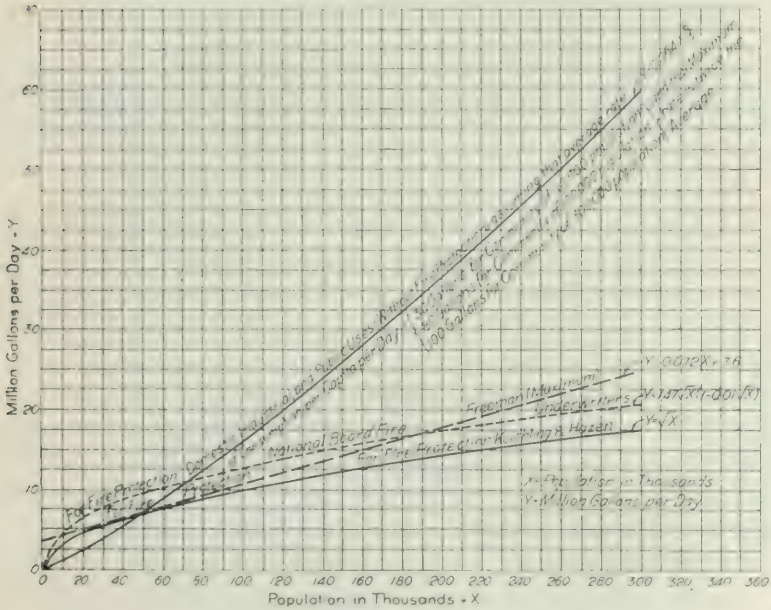


DIAGRAM 1

QUANTITY OF WATER IN MILLION GALS. PER DAY REQUIRED FOR DOMESTIC, INDUSTRIAL AND PUBLIC USES (EXCEPT FIRE PROTECTION) AND FOR FIRE PROTECTION ONLY.

The Hazen standard which was based upon Mr. Kuichling's, if we are correctly informed, is to be found on p. 947 of the *American Civil Engineers' Pocketbook*, recently published:

For average American conditions take the square root of the population in thousands, and the quotient* is the rate in millions of gallons of water per day at which water should be provided for fire service.

*Result.

Mr. Hazen suggests that the required capacity of the pipe system be found by adding to the fire protection service demands, as figured above, the average annual rate of consumption, increased by an allowance of 20 gallons per capita to cover ordinary fluctuations in draft, or if these fluctuations are unusually great, as much as 30 to 40 gallons per capita.

From a study of this subject some years ago, Mr. Kuichling concluded[1] that the number of efficient fire streams required in our American towns and cities might be expressed by the formula:

(1) $y = 2.8\ \sqrt{X}$ where y = the necessary number of such streams, and X = the number of thousands of population.

and if we assume that each such stream shall discharge about 250 gallons per minute, the resulting delivery from the fire hydrants will be at the rate of:

(2) $700\ \sqrt{X}$ gallons per minute, or

(3) $\sqrt{X}$ million gallons per day.

This discharging capacity is regarded as sufficient, except in case of a general conflagration, when help is required from neighboring communities and natural bodies of water in the vicinity are drawn upon by the additional steam fire engines.

If we assume that the average daily consumption per capita for domestic, industrial and public purposes (exclusive of fire protection service), increases with the population, from 50 gallons for communities having a population of 10,000 to 80 gallons for 100,000, and 100 gallons for 300,000, the variation may be expressed approximately by the relation

(4) $z = 32\ \sqrt[5]{X}$ where z = the *average* per capita consumption in gallons per day.

This will make the maximum draft from the distributing system for domestic, industrial and public uses (other than for fire hydrants) at the rate of

(5) $44.4X^{6/5}$ gallons per minute, or

(6) $0.064X^{6/5}$ million gallons per day, when the maximum rate is assumed to be *twice* the average, and

[1] "The Financial Management of Water Works," *Trans. Am. Soc. C. E.*, vol. xxxviii, p. 15.

(7) $0.048X^{6.5}$ million gallons per day, when the maximum rate is assumed to be *one and one-half times* the average.

Therefore the *maximum draft*, for combined fire protection service and domestic, industrial and public uses, is

(8) $1\ \overline{X}+0.064X^{6.5}$ million gallons per day, when the maximum domestic rate is *twice* the average, and

(9) $1\ X+0.048X^{6.5}$ million gallons per day, when maximum domestic rate is *one and one-half times* the average,

and the ratio of the portion of the distribution pipe system devoted to fire protection service, to the total carrying capacity of the distribution pipe system,

(10) $\dfrac{\sqrt{X}}{1\ \overline{X}+0.064X^{6.5}}$ and

(11) $\dfrac{\sqrt{X}}{1\ \overline{X}+0.048X^{6/5}}$, for the two cases cited.

Again, if it is assumed that *without* fire hydrant service a distributing pipe system must be designed for a maximum rate of *twice* the average for domestic and industrial uses, whereas *with* fire hydrant service the maximum rate for domestic and industrial uses may be taken at *one and one-half times* the average rate, the ratio of the difference between the required carrying capacities with and without fire hydrant service to the carrying capacity with such service becomes

(12) $$\frac{1\ \overline{X}+0.048X^{6.5}-0.064X^{6.5}}{1\ \overline{X}+0.048X^{6.5}}=\frac{1\ X-0.016X^{6.5}}{1\ \overline{X}+0.048X^{6/5}}$$

It will be noted that this ratio reduces to zero when $X=367.74$, which means that in a city of 367,740 population, the pipe system must be of the same size to provide for a maximum rate of draft of *two* times the average draft for domestic and industrial uses *without* fire hydrant service, as that which would be required by a maximum draft of *one and one-half times* the average draft for domestic and industrial uses *with* fire hydrant service.

It is also possible to determine the ratio $\dfrac{D}{d}$ of the diameters of two supply mains, one of which (D) is adapted to carrying the

combined fire, and domestic and industrial supply, while the other (*d*) is capable of delivering only the domestic and industrial supply, both pipes having the same hydraulic gradient. Under a given grade the pipe discharge varies as the five halves power of the diameter. If the cost of the pipe per linear foot is expressed in terms of the diameter, the difference in the cost of the two lines may be computed. For the distributing system, however, the relative and absolute amounts of water required for fire hydrant service on the one hand and for domestic and industrial uses on the other will vary in different parts of the city, and hence a general formula covering the entire system cannot be made, as each principal division of the network of pipes must be considered separately with reference to the particular drafts for fire hydrant and domestic purposes.

The results of the application of these principles to each of the three assumed conditions are given in the following table:

TABLE III

Showing Percentage of Total Carrying Capacity of the Distribution Pipe System of a Water Works Plant, which is Required by Furnishing Fire Hydrant Service; Derived by a Comparison of a System Furnishing both Domestic Service and Fire Hydrant Service, with one Furnishing only Domestic Service (including in the term "Domestic Service," Industrial and Public Uses, other than Fire Hydrant Service). Based upon the Kuichling Formula.

	POPULATION							
	10,000	25,000	50,000	100,000	150,000	200,000	250,000	300,000
	per cent	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*
1. When maximum rate for domestic service is assumed to be 1½ *times* the average daily rate therefor, in both plants	80.6	68.6	57.4	45.3	38.5	33.8	30.4	27.8
2. When maximum rate for domestic service is assumed to be *twice* the average daily rate therefor, in both plants	77.6	62.2	50.2	30.4	31.9	27.7	24.7	22.4
3. When maximum rate for domestic service is assumed to be *twice* the average daily rate therefor, in the plant furnishing only domestic service, and 1½ *times* the average daily rate therefor in the plant furnishing both domestic and fire protection service	74.1	58.1	43.2	27.1	17.9	11.7	7.2	3.7

NOTE:—The authors have assumed in this paper that the third set of conditions is probably of most general applicability and have given consideration, in making their final figures, to similar figures based upon the requirements of the National Board of Fire Underwriters.

TABLE IV

Showing the Relative Diameter of the Supply Main Required for Combined Domestic and Fire Service, to the Diameter of the Supply Main Required solely for Domestic Service (including, in the term "Domestic Service," Industrial and Public Uses, excluding Public Hydrant Service). Based upon Kuichling Formula.

	POPULATION							
	10,000	25,000	50,000	100,000	150,000	200,000	250,000	300,000
1. When maximum rate for domestic service is assumed to be 1½ *times* the average daily rate therefor, in both plants.	1.927	1.590	1.407	1.273	1.214	1.179	1.153	1.139
2. When maximum rate for domestic service is assumed to be *twice* the average daily rate therefor, in both plants.	1.762	1.475	1.322	1.214	1.166	1.139	1.120	1.107
3. When maximum rate for domestic service is assumed to be *twice* the average daily rate therefor, in the plant furnishing only domestic service, and 1½ *times* the average daily rate therefor in the plant furnishing both domestic and fire protection service.	1.718	1.417	1.254	1.135	1.082	1.051	1.030	1.015

EXAMPLE:—From this table it appears that in a city having a population of 100,000 the ratio of the diameter of the supply main required for combined domestic, industrial, and public uses, as well as for fire hydrant service, to the diameter of the supply main which would serve the former uses only, excluding public fire hydrant service, is as 1.135 to 1.

NOTE:—The authors have assumed in this paper that the third set of conditions is probably of most general applicability, and have given consideration, in making their final figures, to similar figures based upon the requirements of the National Board of Fire Underwriters.

In the following tabulation are given the actual quantities of water in gallons per minute, reported by the National Board of Fire Underwriters, as "necessary for fire fighting purposes, in excess of domestic consumption," for the cities named.

TABLE V

CITY	POPULATION	DATE	QUANTITY OF WATER CALLED FOR; GALLONS PER MINUTE		
			Main Feeders to C. V. D	About any Block	
				C.V.D.*	Mfg.
Pittsburgh, Pa	500,000	June 1909	18,000		12,000
San Francisco, Cal	450,000	July 1910		15,000	
Cleveland, O	440,000	Aug. 1906	20,000		
Buffalo, N. Y	415,000	Sept. 1909	18,000		12,000
New Orleans, La	360,000	May 1909	15,000	12,000	
Cincinnati, O	353,000	May 1909	16,000		12,000
Los Angeles, Cal	350,000	May 1910	18,000	12,000	10,000
Milwaukee, Wis	313,000	Oct. 1906		10,000	
Minneapolis, Minn	285,000	Nov. 1907			
Seattle, Wash	284,000	Feb. 1910		12,000	10,000
Kansas City, Mo	250,000–325,000	Aug. 1907		10,000	6,000–8,000
Louisville, Ky	235,000	Sept. 1906		10,000	
St. Paul, Minn	210,000	Oct. 1907		10,000	5,000–10,000
Portland, Ore	207,000	Dec. 1910		12,000	5,000–10,000
Denver, Colo	175,000	Aug. 1906		10,000	
Toledo, O	170,000	Dec. 1908		10,000	7,500–10,000
Memphis, Tenn	170,000	Aug. 1909		10,000	5,000–10,000
Oakland, Cal	150,000	Oct. 1910		7,000	3,000–6,000
Omaha, Neb	130,000–150,000	Dec. 1907		10,000	5,000–8,000
New Haven, Conn	125,000	May 1908			10,000
San Antonio, Tex	120,000	Apr. 1910		7,500	3,000–5,000
Scranton, Pa	120,000	Sept. 1906		10,000	
Nashville, Tenn	115,800–164,000	Feb. 1907		10,000	
St. Joseph, Mo	118,000	Oct. 1907		10,000	3,000–5,000
Tacoma, Wash	115,000	Mar. 1910		10,000	3,000–5,000
Atlanta, Ga	114,000	Aug. 1909			10,000
Fall River, Mass	112,600	Apr. 1908			10,000
Spokane, Wash	110,000	Aug. 1910		10,000	4,000–6,000
Dayton, O	106,000	Mar. 1909			7,000–10,000
Grand Rapids, Mich	102,000	July 1907		10,000	5,000–10,000
Hartford, Conn	100,000	Mar. 1908			10,000
Kansas City, Kan	100,000	Sept. 1907			7,000–8,000
Dallas, Tex	100,000	Mar. 1910		10,000	5,000–8,000
Cambridge, Mass	98,000	Nov. 1906			5,000–10,000
Lowell, Mass	96,300	Sept. 1908			10,000
Reading, Pa	96,000	Nov. 1908			
Richmond, Va	95,000	Apr. 1906	10,000		
Camden, N. J	93,000	Feb. 1908			5,000–7,000
New Bedford, Mass	90,300	Mar. 1908			7,000
Houston, Tex	90,000	June 1910		8,000	4,000–6,000
Wilmington, Del	90,000	Jan. 1907			10,000
Des Moines, Ia	84,000	Jan. 1909			8,000
Trenton, N. J	84,000	Jan. 1907			10,000
Lynn, Mass	82,000	Oct. 1908			10,000
Salt Lake City, Utah	82,000	Dec. 1909		7,500	3,000–5,000
Lawrence, Mass	78,000	July 1908			10,000
Fort Worth, Tex	75,000	Apr. 1910		7,500	5,000–7,500
Springfield, Mass	75,000	Aug. 1906		10,000	
Peoria, Ill	73,000	Aug. 1909		8,000	5,000–8,000

*C. V. D. signifies "Congested Value District."

TABLE V. Continued

CITY	POPULATION	DATE	QUANTITY OF WATER CALLED FOR: GALLONS PER MINUTE		
			Main Feeders to C.V.D	About any block	
				C.V.D	Mfg.
Waterbury, Conn	73,000	Sept. 1910		7,500	5,000–6,000
Somerville, Mass	71,000	Nov. 1906			5,000–8,000
Duluth, Minn	71,000	Jan. 1908		10,000	5,000–10,000
Evansville, Ind	70,000	Mar. 1911		7,500	4,000–5,000
Norfolk, Va	70,000	Apr. 1909		7,000	
Schenectady, N. Y	70,000	Feb. 1909			8,000
Erie, Pa	70,000	Nov. 1908			8,000
Manchester, N. H	70,000	Nov. 1909		7,500	4,000–6,000
Utica, N. Y	68,000	Mar. 1908			5,000–8,000
Elizabeth, N. J	67,500	Oct. 1909			6,000
Harrisburg, Pa.....	65,000	Oct. 1906		8,000	
Fort Wayne, Ind....	64,000	Feb. 1911		7,000	3,000–4,000
Wilkes-Barre, Pa	62,000	*Oct. 1906		8,000	
Portland, Maine	60,000	Mar. 1908		10,000	5,000–8,000
Terre Haute, Ind	58,000	Mar. 1911		6,500	3,000–4,000
Charleston, S. C	56,000	Apr. 1906	10,000		
Montgomery, Ala	55,000	May 1907		7,000	
Passaic, N. J	55,000	May 1910			6,000
Chattanooga, Tenn	55,000	†July 1907		7,000	
South Bend, Ind....	54,000	Jan. 1911		7,500	4,000–5,000
Mobile, Ala	53,500	July 1909			7,500–6,000
Brockton, Mass.....	53,000	July 1908			7,000
Altoona, Pa.....	51,000	Feb. 1908			8,000
Lancaster, Pa.....	50,000	Dec. 1909		8,000	6,000
Lincoln, Neb	50,000	Nov. 1907			6,000
San Diego, Cal	50,000	May 1910		7,000	3,000–6,000
Birmingham, Ala	55,000	Aug. 1909		10,000	6,000
York, Pa	49,000	Jan. 1910		7,500	4,000–6,000
Pawtucket, R. I	46,000	Aug. 1908			8,000
Binghamton, N. Y	45,500	Dec. 1908			6,000–8,000
El Paso, Tex	45,000	Mar. 1910		6,500	3,000–5,000
Rockford, Ill	45,000	Aug. 1909		7,500	5,000–7,500
Sacramento, Cal	45,000	Jan. 1911		7,500	5,000
Wheeling, W. Va	45,000	May 1907			7,000
Jacksonville, Fla	45,000	Mar. 1907		6,000	
Davenport, Ia	43,000	Dec. 1909		7,500	5,000–7,500
McKeesport, Pa	43,000	Nov. 1910		6,000	4,000
Elmira, N. Y	42,000	July 1910			5,000
Springfield, Ill	41,500	Dec. 1908			6,000
Berkeley, Cal	40,500	Oct. 1910			3,000–5,000
Quincy, Ill	40,500	Jan. 1910		7,000	5,000–7,000
Malden, Mass	40,000	Dec. 1906			5,000–7,000
Haverhill, Mass	40,000	Aug. 1907		6,000	3,000–5,000
Superior, Wis	40,000	Jan. 1908		5,000	
Butte, Mont	39,000	Nov. 1910		7,500	5,000
Galveston, Tex	38,800	Apr. 1910		7,000	3,500–5,000
Macon, Ga	38,000	Mar. 1907		5,000	
Salem, Mass	38,000	July 1907		6,000	
Woonsocket, R. I	38,000	Jan. 1911			6,000

*Wilkes-Barre, 104,000 within three miles radius.

†Chattanooga, 90,000 within three miles radius.

‡1910 population, 152,559.

TABLE V—Continued

CITY	POPULATION	DATE	QUANTITY OF WATER CALLED FOR; GALLONS PER MINUTE		
			Main Feeders to C.V.D.	About any block	
				C.V.D.	Mfg.
Chelsea, Mass.	37,000	Nov. 1906			5,000–7,000
Tampa, Fla.	37,000	Apr. 1907		5,000	
Austin, Tex.	35,000	June 1910		6,000	3,000–5,000
Fitchburg, Mass.	35,000	Dec. 1907			6,000
Lexington, Ky.	35,000	Dec. 1910		5,000	3,000–4,000
South Omaha, Neb.	35,000	Dec. 1907		5,000	
Roanoke, Va.	33,000	June 1907		5,000	
Jamestown, N. Y.	32,000	Aug. 1910			6,000
Niagara Falls, N. Y.	30,500	Oct. 1910		5,000	3,000–4,000
Ogden, Utah	30,000	Dec. 1909			4,000
Waco, Tex.	30,000	Apr. 1910		6,000	4,000
Colorado Springs, Col.	29,000	Jan. 1911			5,000
Everett, Mass.	29,000	Dec. 1906		5,000	
Quincy, Mass.	29,000	Jan. 1907			5,000–7,000
San José, Cal.	29,000	Oct. 1910		6,500	3,000–5,000
Columbia, S. C.	28,000	Apr. 1907		5,000	
New Brunswick, N. J.	28,000	Dec. 1909			6,000
Norwich, Conn.	28,000	Mar. 1911			5,000
Petersburg, Va.	27,000	June 1907		5,000	
Bangor, Me.	27,000	Oct. 1907		5,000	3,000–5,000
Gloucester, Mass.	26,000	July 1907		5,000	
Charlotte, N. C.	26,000	*Apr. 1907		5,000	
Lewiston, Me.	26,000	Aug. 1907			
Columbus, Ga.	25,000	Apr. 1907		4,000	
Beaumont, Tex.	25,000	Aug. 1910		5,000	3,000
Fresno, Cal.	25,000	Feb. 1911		6,000	3,000–5,000
Newport, R. I.	25,000	June 1908		5,000	
Stockton, Cal.	25,000	Dec. 1910		6,500	3,000–5,000
Lynchburg, Va.	24,000	June 1907		5,000	
Oswego, N. Y.	24,000	Aug. 1908		5,000	
Alameda, Cal.	23,500	Oct. 1910			3,000–5,000
Burlington, Vt.	22,000	Dec. 1907			3,000–4,000
Great Falls, Mont.	22,000	Sept. 1910		4,000	
Freeport, Ill.	20,000	Oct. 1909			4,000
Missoula, Mont.	20,000	Nov. 1910			4,000
Lockport, N. Y.	18,000	Feb. 1911			3,500
Helena, Mont.	15,000	Oct. 1910		5,000	
Newburyport, Mass.	15,000	May 1910			3,500
Hornell, N. Y.	14,000	Oct. 1910			3,000
Augusta, Me.	13,000	Oct. 1907		4,000	
Berlin, N. H.	13,000	Nov. 1907		4,000	
Phoenix, Ariz.	12,500	Mar. 1911		4,000	2,500–3,500
Brunswick, Ga.	12,000	Mar. 1907		4,000	
Rome, Ga.	12,000	Apr. 1907		4,000	
Marblehead, Mass.	7,580	Jan. 1908		3,000	

*Charlotte (Greater Charlotte 35,000).

Mr. George W. Booth, Chief Engineer of the Board, adds in comment upon the list:

In the case of the larger cities, it is considered that the possibility of two simultaneous fires in the congested value district is sufficient to justify provision for them.

Structural conditions and the extent of the high value district, and of the conflagration hazard as determined by our engineers in the field, has some bearing on the quantities recommended, as well as the fire department strength of the city under consideration and of its neighbors. Naturally, the population is not always a fair index in these matters.

Upon diagram 2 have been plotted the data contained in the above tabulation, together with a curve prepared by the authors, as representing the general requirements of the National Board of Fire Underwriters, the equation for which is

$$(13) \quad y = 1020 \sqrt{X}\,(1 - 0.01 \sqrt{X})$$

and with Kuichling's old standard

$$(14) \quad y = 700 \sqrt{X}$$

in both of which equations y = gallons per minute
X = population in thousands

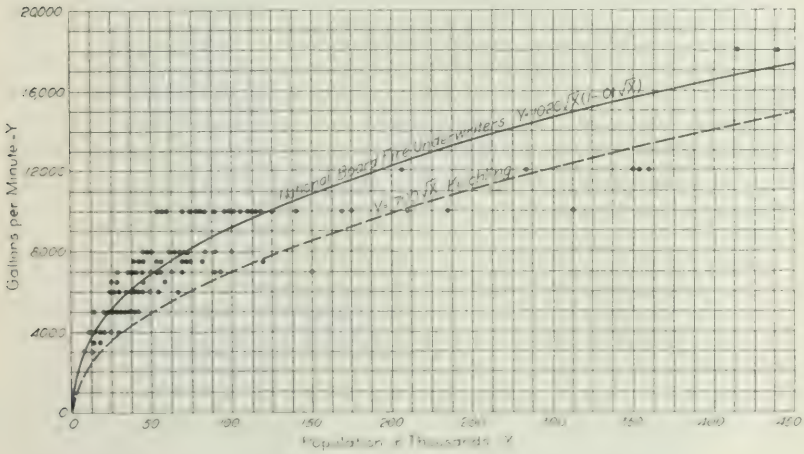


DIAGRAM 2

QUANTITY OF WATER FOR FIRE PROTECTION SERVICE REPORTED BY THE NATIONAL BOARD OF FIRE UNDERWRITERS (1905–1911) AS NECESSARY FOR THE CONGESTED VALUE DISTRICT* OF VARIOUS CITIES, TOGETHER WITH THE RESULTING AVERAGE CURVE† AND THE KUICHLING STANDARD (1897).

* Or main feeders in a limited number of cases.

† Prepared by the authors.

In making comparison of the relative capacities required for domestic, industrial, and public uses, *excluding* fire protection service, as compared with the former *including* fire protection service, the authors of this paper have assumed, first, that under the conditions *excluding* fire protection service, the pipe system must be designed to have a carrying capacity of *double the average daily rate* of water consumption, in order to meet the ordinary fluctuations in demand; second, that under the conditions *including* fire protection service, provision must be made for a maximum demand for water for domestic, industrial, and public uses of *50 per cent in excess of the average rate of demand* therefor, and in addition thereto for the requirements of fire protection service, as determined by the several standards outlined above.

In diagram 3 is shown the per cent of carrying capacity of water works pipe systems required for fire protection, based upon the standard cited for fire protection service, and three different average daily rates of consumption for domestic, industrial and public uses of water, to wit: 50, 100 and 150 gallons per capita daily. Upon this diagram are shown two curves—"A," based upon the Kuichling standard, and "B," based upon the National Board of Fire Underwriters requirements, and both based upon the assumption of a varying per capita consumption for domestic, industrial and public uses of water—of 50 gallons per capita daily for a city of 10,000 population, 80 gallons per capita daily for a city of 100,000 population and 100 gallons per capita daily for a city of 300,000 population.

From curves "A" and "B" it will be seen that upon these assumptions, as to the carrying capacity of the pipe system, there is chargeable to fire protection service:

TABLE VI

Portion of Carrying Capacity of Pipe System, Chargeable to Fire Protection Service.

CITIES HAVING POPULATION OF	PER CENT ACCORDING TO	
	Kuichling standard	National Board of Fire Underwriters 1910 standard
(1)	(2)	(3)
	per cent	*per cent*
10,000	74	83
50,000	43	54
100,000	28	37
200,000	12	19
300,000	4	9

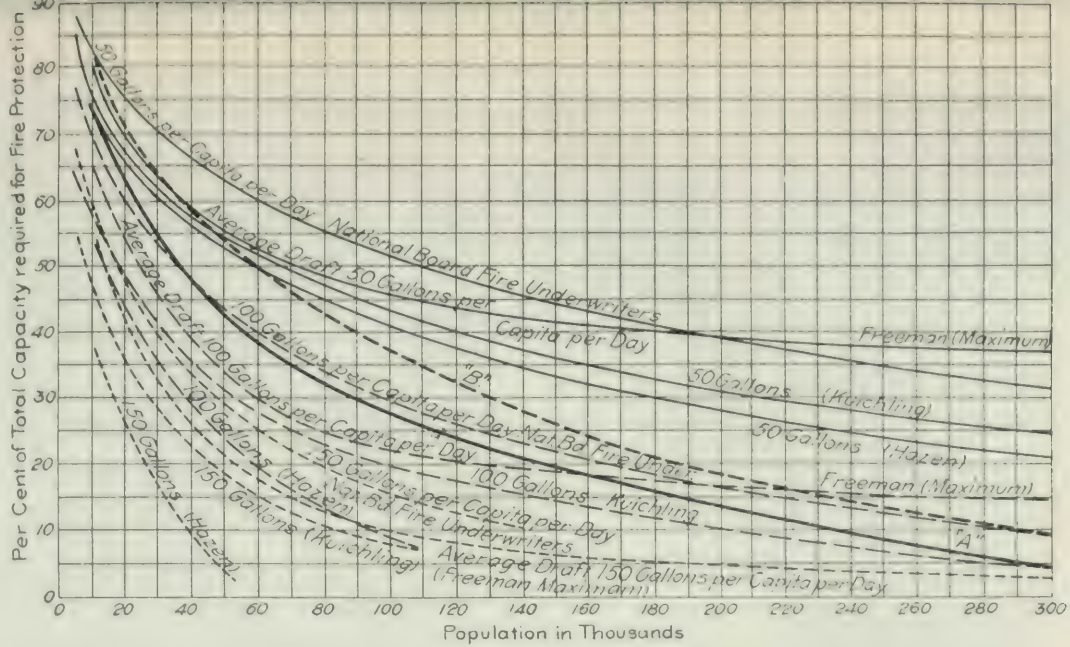


Diagram 3

Per Cent of Total Carrying Capacity of Water Works Pipe Systems Required for Fire Protection.

Maximum Consumption with allowance for Fire Protection calculated by using the Freeman, the Kuichling, the Hazen and the 1910 National Board of Fire Underwriters' Standards.

Maximum Consumption WITHOUT Fire Protection assumed to be TWICE the average daily Per Capita Consumption shown.

WITH Fire Protection the Domestic Consumption to be provided for is assumed to be 1½ TIMES the average domestic consumption in all cases except the Hazen Standard, where 20 gallons per capita daily in excess of average draft are provided for.

Computations based upon an average consumption for Domestic, Industrial, and Public uses of 50, 100 and 150 gallons per Capita per Day, respectively.

Curve "A" drawn by using Kuichling's Standard (1897.)
Curve "B" drawn by using Nat. B'd. Fire Underwriters Standard } and assuming average draft exclusive of Fire Demand of

50 gallons per capita for a city of 10,000 population
80 gallons per capita for a city of 100,000 population
100 gallons per capita for a city of 300,000 population

While it is believed that the minimum values shown on this curve are too low, particularly under the old Kuichling standard, the curve probably clearly indicates the general tendencies.

WATER CONSUMPTION

As bearing upon the question of water consumption, the following figures are of interest, the statistics relating to the United States having been worked up from the United States Census Bureau, Department of Commerce and Labor, Report upon "Statistics of Cities Having Population of over 30,000, for the Year 1907." The figures for England, France and Germany, were worked up from Debauve and Imbeaux's *Distributions d'Eau*, Paris, 1905.

TABLE VII

Average Water Consumption in Cities of the United States, England, France, and Germany

COUNTRY	NUMBER CITIES	RANGE OF POPULATION	CONSUMPTION IN U. S. GALLONS PER CAPITA DAILY		
			Maximum	Minimum	Average
(1)	(2)	(3)	(4)	(5)	(6)
United States	13	300,000–4,225,000	344	76	164
United States	22	100,000– 300,000	230	51	111
United States	34	50,000– 100,000	301	40	116
United States	44	30,000– 50,000	398	26	117
United States	113	30,000–4,225,000	398	26	121
England	37	46,000–6,305,000	83	18	38
France	41	19,000–2,714,000	273	7	54
Germany	38	9,100–1,884,000	66	6	28

VARIATION IN WATER CONSUMPTION

As bearing upon the maximum demand for water, as compared with the average daily consumption throughout the year, the following tabulation reprinted from the *32d Annual Report of the State Board of Health of Massachusetts*, for the year 1900, is significant. It will be seen that the maximum weekly consumption rarely equals double the average weekly consumption for the entire year, while the maximum daily consumption is from two to four times the average daily consumption for the entire year. The minor fluctuations are, however, taken care of by the storage capacity of the reservoirs and the surplus pumping capacity in the case of direct pumping systems. It is believed, therefore, that the assumption made

TABLE VIII

Relation of the Consumption of Water during the Month, Week and Day of Maximum Consumption to the Average for the Year—Average of Six Years from 1895 to 1900, inclusive.

CITY OR TOWN	AVERAGE DAILY CONSUMPTION PER PERSON	MAXIMUM MONTHLY CONSUMPTION		MAXIMUM WEEKLY CONSUMPTION		MAXIMUM DAILY CONSUMPTION	
		Gallons per person per day	Per cent of average for year	Gallons per person per day	Per cent of average for year	Gallons per person per day	Per cent of average for year
Abington and Rockland	39	54	138	63	167	88	223
Andover	54	67	127	74	129	150	264
Attleborough	36	47	130	52	143	88	245
Avon	31	42	137	55	180	109	367
Ayer	37	51	140	66	181	96	265
Beverly	70	98	140	114	163	156	222
Braintree	71	85	123	83	143	137	194
Bridgewater and E. Bridgewater	24	27	116	31	130	41	175
Brockton	36	49	134	49	164	69	232
Brookline	85	105	124	146	160	167	184
Cambridge	81	94	113	109	138	145	180
Canton	40	54	134	64	158	87	216
Cohasset	34	62	177	62	250	95	300
Cottage City	93	251	271	296	318	383	419
Danvers	69	84	119	96	134	127	181
Dedham	71	91	127	103	149	126	183
Easton	21	29	135	38	181	51	245
Fairhaven	48	70	153	73	165	114	258
Fall River	36	43	121	47	130	54	150
Foxborough	50	60	119	68	135	100	200
Framingham	36	44	122	52	143	71	194
Franklin	35	47	136	72	206	82	245
Gardner	62	77	125	86	128	113	169
Gloucester	32	41	129	47	142	64	193
Hyde Park and Milton	42	61	145	62	147	70	166
Ipswich	18	32	173	29	160	100	542
Lawrence	55	62	111	74	134	90	164
Longmeadow	64	90	146	117	185	177	285
Lowell	79	92	117	102	130	118	150
Lynn and Saugus	67	78	116	84	125	118	177
Manchester	76	142	186	163	214	224	296
Mansfield	33	45	134	59	177	79	236
Marblehead	49	70	160	92	187	127	264
Marlborough	37	43	119	44	119	80	220
Maynard	30	43	143	57	180	140	482
Methuen	33	42	126	51	151	80	217
Middleborough	32	41	125	51	160	72	218
Milford and Hopedale	61	74	121	83	136	97	158
Montague	67	80	122	89	127	132	202
Nantucket	32	70	218	80	249	95	296
Natick	42	56	134	80	191	96	232
Needham	50	57	114	64	128	79	158
New Bedford	90	108	119	121	134	143	159

TABLE VIII—Continued

CITY OR TOWN	AVERAGE DAILY CONSUMPTION PER PERSON	MAXIMUM MONTHLY CONSUMPTION		MAXIMUM WEEKLY CONSUMPTION		MAXIMUM DAILY CONSUMPTION	
		Gallons per person per day	Per cent of average for year	Gallons per person per day	Per cent of average for year	Gallons per person per day	Per cent of average for year
Newburyport	41	46	114	52	128	64	157
North Attleborough	30	40	136	39	138	53	176
North Brookfield	35	45	134	62	184	103	308
Norwood	71	84	119	89	129	176	261
Orange	24	31	130	42	173	70	300
Peabody	89	102	114	113	127	139	155
Provincetown	29	52	187	67	224	127	480
Randolph and Holbrook	45	72	161	96	226	131	306
Reading	32	51	154	69	206	111	328
Rockport	34	53	151	73	194	89	266
Salem	67	77	114	80	119	119	178
Sharon	26	57	216	67	258	88	336
Stoughton	43	52	122	59	146	77	192
Taunton	46	53	116	58	127	67	147
Tisbury	37	74	196	93	253	110	304
Wakefield and Stoneham	53	66	124	57	127	102	182
Walpole*	30	40	136	61	188	91	328
Waltham*	76	84	115	99	135	134	188
Ware	32	40	123	43	133	92	283
Webster	34	39	117	42	125	59	175
Wellesley	42	54	130	66	157	82	236
Whitman	29	42	149	54	188	66	231
Woburn	73	90	123	106	145	160	218
Worcester†	58	75	117	86	128	110	165

*Five years only. †Less than six years.

in our comparison—to wit, that with a pipe system designed solely for domestic and industrial uses, the maximum demands should be assumed to be about double the average daily demand, is probably fair, for if the maximum demand should exceed double the average demand, it would at most mean that there would be some fall in the normal pressure under which the water was delivered, and not an actual failure to deliver the required volume of water. In the case of the large community, the ratio would probably be less than double, in other words, the maximum demand would probably be relatively less, as compared with the average demand, than in the smaller community, and this is one reason for modifying curve "A" in the diagram, in its application to the larger communities.

SUB-DIVISION OF COST OF THE PHYSICAL PLANT OF WATER WORKS PROPERTIES

In Table IX following, are shown data relating to the sub-division of the reproduction cost of the physical plant of water works properties, based upon estimates submitted in water works valuations which have come within the experience, or under the observation of the authors.

In Table X are shown similar data kindly furnished to the writers by Mr. John W. Alvord of Chicago; in Table XI data from Mr. Morris Knowles of Pittsburgh; and in Table XII data based upon the published reports of the Railroad Commission of Wisconsin. These results are shown in diagrammatic form in diagram 4.

TABLE IX

Sub-division of Cost of Water Works Properties in per cent of Reproduction Cost of Property including therein Engineering and Contingencies, Organization and Interest during Construction; excluding Going Value and Franchise and other Intangible Values. Based upon experience of L. Metcalf.

CITY POPULATION	CITY IN CENTRAL STATES 241,000	PENNSYLVANIA WATER COMPANY 100,000	SAN ANTONIO 79,000	MACON, GA. 40,000	KNOXVILLE, TENN. 38,000	KENNEBEC WATER DISTRICT 17,000	ITHACA 14,600	LIVERMORE FALLS 3,400 GRAVITY	KITTERY 2,900 GRAVITY
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	per cent	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*
1. Supply	18 2		3.1	13.5	1.4			50	nearly 10
2. Pumping ..	15 8	25 2	19 8	15.9	8 5	17.0			
3. Reservoirs		15 4	2.0	5 8	5.0	4 2			
4. Distribution system	39 0	50 5	65 1	41.8	75.7*	70 1	53‡	50	90 All piping
5. Filter, etc.	10.7			10.2	4.6				
6 Real estate water rights and rights of way .	9 4	1.5	10 0	7 8	4 8	8 7			
7. Organization	0.9	0.9	†	2.2	†	†			
8. Interest during construction ...	6.0	6 5	†	2 8	†	†			
	100 0	100 0	100 0	100 0	100 0	100 0		100	100

*Of this 20 per cent covers service connections and meters.
†Included in general per cent engineering and contingencies, etc.
‡Water Company testimony.

TABLE X

Sub-division of Cost of Water Works Properties in per cent of Reproduction Cost of Property (including therein Engineering and Contingencies, Organization and Interest during Construction; excluding Going Value and Franchise and other Intangible Values). Courtesy of Mr. J. W. Alvord.

Location	Omaha, Neb. (1906)	Des Moines, Iowa (1910)	Peoria, Ill. (1909)	Mississippi River State (1902)	Southern Central State (1910)	Topeka, Kan. (1900)	Middle Western State (1909)	Saugatuck, Mich. (actual) (1904)	Middle Western State (1906)	Mississippi River State (1905)
Population	115,422	86,300	65,865	36,809	35,099	33,608	9,000	707 (1900)	8420 (1900)	4102 (1900)
	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
	per cent	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*
1. Supply		7.3	8 4		14 4		7.6	16.7		
2. Pumping	41.0	8 5	11.4	51 3	15 1‡	31.9	11.8	28.4	29.7	39.4
3. Reservoirs									9.1	
4. Distribution system*	52.6	71.1	59.1	48 7	38 4	66.2	76 5	54 9	61.2	60 6
5. Filters, etc										
6. Real estate, rights of way, etc	2.7	4 4†	9 6†		27 6†	1.9	0.8†			
7. Organization	§	§	§	§	§	§	§			
8. Interest during construction	3.7	8 7	7.9	§	4.5	§	3.3			
		100.0	100.0	100.0	100 0	100 0	100.0	100.0	100.0	100.0

* Includes meter, stock and tools, etc.

† Interest during Construction on this item.

‡ Includes Filters.

§ Included in General per cent Engineering, Contingencies, Preliminary Costs, etc.

TABLE XI

Sub-division of Cost of Water Works Properties in Per Cent of Reproduction Cost of Property (including therein Engineering and Contingencies, Organization and Interest during Construction; excluding Going Value and Franchise and other Intangible Values). Courtesy of Mr. Morris Knowles.

LOCATION	GREATER CITY ALL THREE OF FOLLOWING DIVISIONS COMBINED	PITTSBURG PROPER	ALLEGHENY OR NORTH SIDE	SOUTH SIDE OR FORMER MONONGAHELA WATER CO.
POPULATION	498,965	284,180	132,283	82,243
	(28) *per cent*	(29) *per cent*	(30) *per cent*	(31) *per cent*
1. Supply	0.3		1.2	0.6
2. Pumping	16.1	11.7	31.0	11.4
3. Reservoirs	7.7	10.0	1.8	6.2
4. Distribution system	38.3	34.2	41.5	56.4
5. Filter, etc.	23.6	39.0	11.0	11.0
6. Real estate water rights and rights of way	2.8	3.1	2.4	2.4
7. Organization	9.3	9.2	8.9	10.0
8. Interest during construction	1.9	1.8	2.2	2.0
	100.0	100.0	100.0	100.0

NOTE: The figures given for population represent the population of the sections of the city in which the city furnishes water, and do not mean the entire population of the city nor the number of persons served.

RESULTING ESTIMATE OF COST OF FIRE PROTECTION SERVICE

Upon diagram 4 have been plotted the data given in Tables IX to XII, relating to the percentage of the reproduction cost of the physical plant of water works systems, chargeable to the distribution pipe system, and curve "C" indicating the general average conditions; curves "A" and "B," showing the percentage of the total carrying capacity of the pipe distribution system, required for fire protection service, replotted from diagram 3; and curves "D and "E" showing the resulting percentage of total cost of the distribution system of water works plants, chargeable to fire protection service, based upon curve "C," and the requirements of the Kuichling and the National Board of Fire Underwriters' standards, respectively. It will be noted that curves "D" and "E" are based *solely upon distribution pipe system costs*, whereas the fire protection service may involve some slight additional cost in supply and reservoir systems, and substantial increase in cost of pumping capacity. The costs involved

TABLE XII

Sub-division of Cost of Water Works Properties in Per Cent of Reproduction Cost of Property (including therein Engineering and Contingencies, Organization and Interest during Construction; excluding Going Value and Franchise and other Intangible Values). Based upon Reports of the Railroad Commission of Wisconsin.

City	Madison, Wis. (1909)	Fond du Lac, Wis.	Appleton, Wis.	Ashland, Wis.	Stevens Point, Wis.	Chippewa Falls, Wis. (1908)	Antigo, Wis.	Jefferson, Wis.	Darlington, Wis. (1909)	Washburn, Wis. (1910)	Lake Geneva, Wis.
Population	24,894	19,500	18,900	11,594	11,150	8700	7000	2500	2000	4924 (1905)	2900
	(20)	(21)	(22)	(23)	(23a)	(24)	(25)	(26)	(27)	(25a)	(25b)
	per cent	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*
1. Supply	9.1	7.0	5.4	16.4	3.4	3.8	7.2	6.8	1.6	4.8	12.3
2. Pumping*	13.1	17.1	21.1	10.3	19.2	11.3	10.9	14.0	11.3	15.3	21.0
3. Reservoirs	4.7	3.4	5.1		7.8	5.9	6.4	8.9	6.0	6.7	6.7
4. Distribution system†	63.8	70.7	65.7	60.0	69.0	78.9	63.6	67.8	80.7	73.0	59.1
5. Filter, etc				12.0							
6. Real estate, water rights and rights of way	9.3	1.8	2.7	1.3	0.6	0.1	8.9	2.5	0.4	0.2	0.9
7. Organization	‡	‡	‡		‡	‡	‡	‡	‡	‡	‡
8. Interest during construction	‡	‡	‡		‡	‡	3.0	‡	‡	‡	‡
	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

* Pumping includes buildings and miscellaneous structures.

†Includes office furniture, tools, horses and wagons, etc. Non-operative property not included.

‡ Included in general per cent engineering and contingencies, etc.

** Based on grand total population.

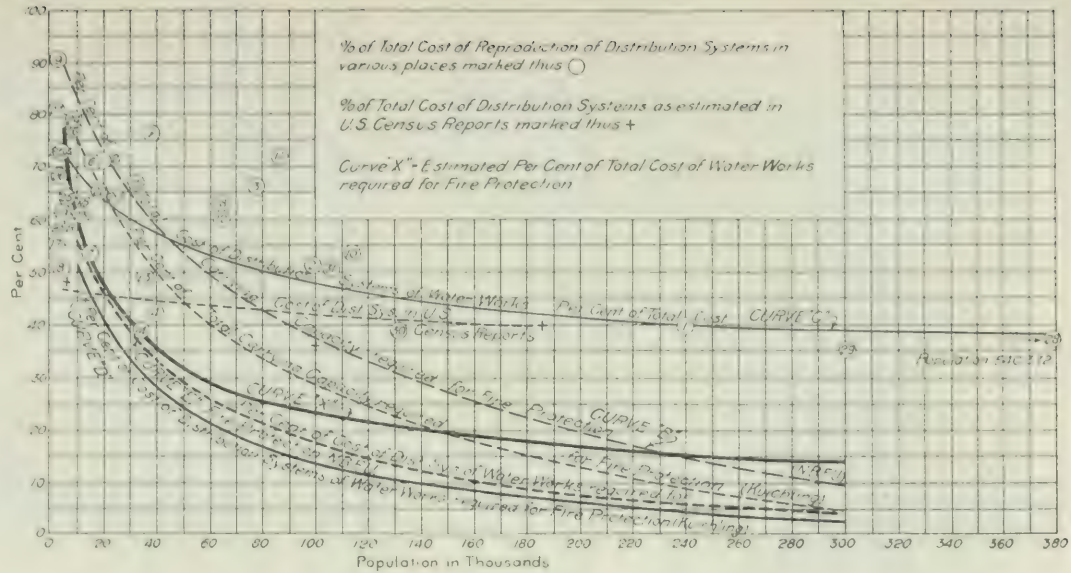


DIAGRAM 4

ESTIMATED PER CENT OF TOTAL CAPACITY OF PIPE LINES REQUIRED FOR FIRE PROTECTION, AND ESTIMATED PER CENT WHOLE COST OF DISTRIBUTION SYSTEM, AND OF FIRE PROTECTION SERVICE AND OF THE TOTAL COST OF WATER WORKS.

by these increased needs will be much more important in small plants than in large plants, except when independent high pressure fire protection systems are required.

Curve X, shown also in diagram 5, the equation for which is

$$y = \frac{147}{X^{0.31}} - 12.1 \quad \text{in which } y = \text{per cent of total cost}$$

$$X = \text{population in thousands}$$

represents the judgment of the authors as to the approximate percentage, of the total cost of water works, involved by the requirements of fire protection service, taking into consideration not only the distribution pipe system but also any additional cost involved in the water supply and reservoir systems, pumping capacity, etc., and the limitations of the assumptions made above as to per capita consumption and fluctuations in rate of water consumption in cities of different sizes. Attention is again called to the fact that these studies are of comparative value only, as indicating general tendencies and that substantial departure from normal conditions, as outlined, is to be anticipated in individual plants, so that if reliable information is desired concerning any particular plant, the studies should be based upon the actual conditions existing at that plant. For comparative purposes, however, the curve is suggestive. The data shown by these curves are also given in tabular form below:

TABLE XIII

Estimated Cost of Portion of Water Works Plant, Chargeable to Fire Protection Service

POPULATION	COST OF DISTRIBUTING PIPE SYSTEM IN PER CENT OF TOTAL COST OF WATER WORKS "CURVE C"	PER CENT OF COST OF DISTRIBUTING PIPE SYSTEM CHARGEABLE TO FIRE PROTECTION SERVICE UNDER		PER CENT OF COST OF ENTIRE PLANT CHARGEABLE TO FIRE PROTECTION SERVICE. "CURVE X"
		Kuichling standard "Curve D"	National Board of Fire Underwriters Standard "Curve E"	
(1)	(2)	(3)	(4)	(5)
	per cent	*per cent*	*per cent*	*per cent*
5,000	72			77
10,000	68	50.3	56.0	60
50,000	54	23.8	29.0	32
100,000	47	13.1	17.5	23
300,000	39	1.6	4.0	13

It is evident that the relative cost of the portion of the plant devoted to public fire protection service is greater in small cities than in large ones, and greater also in purely residential cities than in manufacturing cities.

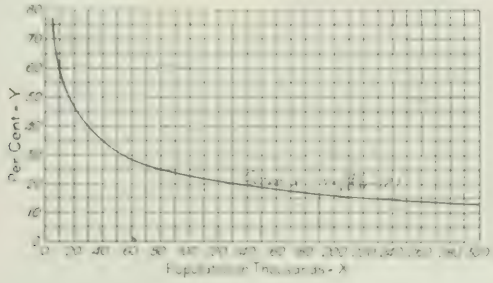


Diagram 5

Estimated Portion of the Total Cost of Water Works Necessitate by Fire Protection Requirements.

Thus the conditions recently analyzed by the writers, in a plant serving a manufacturing city of approximately 100,000 population, showed the following approximate sub-division of reproduction cost.

	per cen
Domestic service	44
Industrial service	37
Public fire protection	19

But it should be added that the relative capacity of pipe system required by the different classes of service was estimated as follows:

	per cent
Domestic service	22
Industrial service	31
Fire protection service	47

Had the demands for industrial service been substantially less—as would have been the case in a residential city—the relative cost of the public fire protection service would have been substantially increased.

A side light upon the cost of fire protection service, is thrown by the United States Geological Survey, Bulletin 418, upon "The Fire Tax and Waste of Structural Materials in the United States," written by Herbert M. Wilson and John L. Cochrane. It must be remembered, however, that the results submitted are based upon

TABLE XIV

Based upon Data Contained in U. S. Geological Survey Bulletin 418, "The Fire Tax and Waste of Structural Materials in the United States," by Herbert M. Wilson and John L. Cochrane, 1910, pp. 18–19. Cost of Water Works 1907

SUB-DIVISION OF COST OF WATER WORKS AND RELATIVE AMOUNTS CHARGEABLE TO DOMESTIC AND FIRE SERVICE

BRANCH OR SUBDIVISION OF WORKS	POPULATION 100,000 AND OVER	30,000 TO 100,000	5,000 TO 30,000	UNDER 5,000	TOTAL FOR UNITED STATES
1. Cost per capita	$32.72	$29.06	$23.60	$16.59	$27.21
2. Total cost	$591,222,244	$184,803,174	$235,718,458	$117,503,656	$1,129,247,532
Percentage of Cost of Entire System and Sub-division Between Domestic and Fire Service					
	per cent	*per cent*	*per cent*	*per cent*	*per cent*
3. Source of supply	57.4 D=96.9	49.4 D=85.7	52.7 D=75.6	46.7 D=75.1	54.0 D=89.1
	F =3.1	F =13.3	F =24.4	F =24.9	F =10.9
4. Distribution system	37.9 D=77.2	46.6 D=72.8	43.3 D=65.8	47.4 D=68.1	41.5 D=72.8
	F =22.8	F =27.2	F =34.2	F =31.9	F =27.2
5. Tons of pipe	D=72.3	D=74.4	D=69.3	D=68.0	D=71.6
	F =27.7	F =25.6	F =30.7	F =32.0	F =28 4
6. Cost of hydrants	1 4 F =100.	2.7 F =100.	4.0 F =100.	5.9 F =100.	2.0 F =100.
7. High pressure fire system	3.4 F =100.	1.2 F =100.	F =100.		2.0 F =100.
8. Total	100. D=84.8	100. D=76.8	100. D=68.3	100. D=67.5	100. D=78.2
	F =15 2	F =22 2	F =31.7	F =32.5	F =21.8

CLASSIFICATION BY GEOGRAPHICAL DIVISIONS

	TOTAL FOR UNITED STATES	MIDDLE AND NEW ENGLAND STATES	CENTRAL STATES	SOUTHERN AND SOUTH EASTERN STATES	ROCKY MOUNTAIN AND WESTERN STATES	PACIFIC SLOPE
1 Cost per capita	$27 21	$32 19	$20 35	$19 34	$63 77	$28 96
2 Total cost	$1,129,247,532	$623,221,159	$308,163,578	$75,737,475	$60,569,780	$61,615,540

Percentage of Cost of Entire System and Sub-division between Domestic and Fire Service

	per cent	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*
3 Source of supply	51 0 D = 89 1	60 1 D = 92 4	43 6 D = 82 8	45 7 D = 81 7	51.1 D = 95 2	56 8 D = 80 2
	F = 10 9	F = 7 6	F = 17 2	F = 18 3	F = 4 8	F = 19 8
4 Distribution	41 5 D = 72 8	35 5 D = 75 7	51 5 D = 70 3	48 0 D = 67 3	42.8 D = 73 2	41 8 D = 71 6
	F = 27 2	F = 24 3	F = 29 7	F = 32 7	F = 26 8	F = 28 4
5 Tons of pipe	D = 71 6	D = 73 0	D = 70 1	D = 69 2	D = 70 8	D = 75 5
	F = 28 4	F = 27 0	F = 29 9	F = 30 8	F = 29 2	F = 24 5
6 Hydrants	2 6 F = 100	1 5 F = 100	4 1 F = 100	4 3 F = 100	6.1 F = 100	1 4 F = 100
7 High Pressure	2 0 F = 100	2 9 F = 100	0 8 F = 100	2 0 F = 100		
8 Total	100 D = 78 2	100 D = 82 4	100. D = 72 2	100 D = 69 7	100. D = 79 9	100 D = 75 5
	F = 21 8	F = 17 6	F = 27 8	F = 30 3	F = 20 1	F = 24 5

the replies to a circular letter sent out by the Bureau to the superintendents of water works of the various cities in this country. Fundamentally, therefore, the replies are based upon the judgment of the superintendents and probably not upon any actual computations by them. In this report, Messrs. Wilson and Cochrane say:

> To the question, "What proportion of the cost of the construction of water works should be legitimately charged to domestic service, and what proportion to fire protection service?" engineers generally will reply that the cost should be equally divided, except in the larger cities where a much greater proportion should be charged to domestic service.
>
> The results of this inquiry, incomplete though it is, would indicate for the whole United States an average of 22 per cent of the total expenditure for water supplies, or less than $\frac{1}{4}$ of the total cost of water works systems is due to the additional supplies necessary for protection against fires of such magnitude as may be propagated beyond building of origin.

The data submitted by Wilson and Cochrane have been worked up into unit figures as being of greater interest to engineers, and are submitted in Table XIVa, following, the summarized result being substantially as shown below:

TABLE XIVa

IN UNITED STATES CITIES HAVING POPULATION	COST OF THE FIRE PUBLIC SERVICE ALLOWANCE OF
Under 5,000	32.5
5,000-30,000	31.7
30,000-100,000	22.2
Above 100,000	15.2
Average	21.8

Attention is again called, however, to the unreliability of the above figures, for they are based upon the opinion ("guess" would be a fairer word to use) of the water works superintendents to whom the card of inquiry was sent, and not upon a critical comparative study of cost of the portion of the plant chargeable to fire protection service.

COST OF INSTALLING EXTRA HYDRANTS

The cost of installing extra hydrants will vary with the different conditions under which the work has to be prosecuted. Upon the large mains, particularly those in the heart of the city, the connec-

tion is likely to be made through the agency of a Smith tapping machine, without interruption of the service, placing a valve upon the hydrant branch. In the city, not only will various obstructions be encountered but the paving of the streets will add substantially to the cost of the work. In the outlying residential districts, particularly where the hydrants are inserted on small mains such as 6-inch pipe, gates may be omitted from the hydrant branches and little or no paving may be encountered in the work. The general range of probable costs of cutting in hydrants may perhaps be said to lie between $50 and $150 per hydrant, as follows:

TABLE XV

ITEM	DIAMETER OF PIPE.		
	24-inch	12-inch	6-inch
Excavation and backfilling	$ 8– $12	$8	
Paving	12– 20	15	
Smith's sleeve, valve and box	62– 62	31	
Labor, lead and yarn	8– 10	5	$7*
Hydrant	28– 32	30	30
C. I. pipe 20 feet 6 inches and hydrant branch ..	8– 10	8	19†
Total	$126–$146	$97	$56

*Cutting in special.
†Includes excavation, laying and backfill, etc.

GROWTH IN DEMAND FOR INDEPENDENT HIGH PRESSURE FIRE PROTECTION PIPE SYSTEM IN LARGE CITIES

One of the factors tending to increase the cost of the portion of the water works plant chargeable to fire protection service in our largest cities, is to be found in the demand for a separate piping system devoted solely to the furnishing of water for hydrant service, not only in large volume but under much greater pressure than that which can be furnished ordinarily through the domestic piping system. This growth in demand is the outcome of higher insurance standards brought about indirectly by the disastrous losses entailed by some of the terrible conflagrations which have been suffered by a number of our American cities,—such for instance as the Chicago fire, the Boston fire, the Baltimore fire, and the San Francisco fire, and by the admirable studies of and resulting recommendations concerning, the water supply and fire fighting facilities of our larger American cities, made by the National Board of Fire Underwriters within the

past five years. The effect of the building of sky-scrapers should also not be lost sight of. Unfortunately, the requirements of the building code as to the use of fireproof or slow-burning construction, have not kept pace with building construction, and the problem has unfortunately been approached rather from the point of putting out the fire than of substantially reducing if not preventing the possibility of its development.

OPERATING CHARGES UPON PUBLIC FIRE PROTECTION SERVICE

The data relating to the operating and maintenance charges involved in the fire protection service are meager. It is believed that these charges lie between 5 and 10 per cent of the total annual operation and maintenance charges, including taxes but excluding depreciation, interest, and profit allowances.

If we assume the gross income for small works to be 15 per cent per annum of the value of the works, and the portion of the gross income chargeable to hydrant protection service to be 10 per cent, we should have an annual cost of operation and maintenance, including taxes, in terms of the value of the property, amounting to approximately 1.5 per cent; while for large works we might assume for the corresponding figures 6 per cent $\times$ 10 per cent = 0.6 per cent. In other words, the range of operating charges would seem to lie between $1\frac{1}{2}$ per cent and $\frac{1}{2}$ per cent of the value of the property, depending upon the size of the community. While these limits will undoubtedly be exceeded in individual cases, these estimates will perhaps serve for a general analysis of the problem. The limited amount of data upon which the above figures are predicated, however, must be clearly borne in mind.

For depreciation, interest, and profit allowances we might assume approximately:

Depreciation	1 per cent to 2 per cent
Interest	6 per cent to 6 per cent
Profit	0 per cent to 2 per cent
Total	7 per cent to 10 per cent

or say 8 per cent of the value of the portion of the system involved by fire protection service.

Applying these figures or assumptions to the general range of per capita values of water works, the following table results:

TABLE XV

Estimated Approximate per Capita Cost of Public Fire Hydrant Service

ITEM	TOWNS OF 5,000 POPULATION	CITIES OF 50,000 POPULATION	LARGEST CITIES
(1)	(2)	(3)	(4)
1.—Value per capita of water works	$20	$30	$35
2.—Percentage of portion chargeable to public fire hydrant service	77%	32%	15%
3.—Per capita value chargeable to public fire hydrant service	$15.40	$9.60	$5.25
4.—Operation and maintenance charges—approximately 10 per cent × 15 per cent = 1.5 per cent of value of entire plant, for towns, 7.5 per cent × 12.5 per cent = 1 per cent for average cities; 6 per cent × 10 per cent = 0.6 per cent for largest cities	.30	.28	.21
5.—Annual charges on public fire hydrant service, covering depreciation and interest, say 8 per cent of Item 3	1.23	.77	42
6.—Total annual charges per capita	$1.53	$1.05	$0.63

It is perhaps fair to infer, in default of more exact information that the *average cost of public fire hydrant service may be approximately $1.00 per capita, with variations of about 40 per cent, more or less;* though every plant must be examined individually as the range of variation is obviously a large one. Few works receive an aggregate hydrant rental approaching this amount; which is but another ground for the authors' contention that hydrant rentals rarely bear any relation to the cost of the service, usually being "traded out" as an offset to franchise and other business considerations.

The relation between per capita cost of fire protection service and the corresponding annual cost per hydrant, based upon current practice in the United States as to number of hydrants per mile of distribution pipe system, is indicated in the following table, but attention is called to the fact that with increase in the number of hydrants per mile of distribution pipe system, the annual cost per hydrant would be correspondingly reduced; also to the need of caution in the use of this table, for reasons previously stated.

In this connection it is perhaps interesting to note that the Bureau of the Census, United States Department of Commerce and Labor, in its recent special reports upon "Statistics of Cities having a Population of over 30,000," has made allowance, in figuring the "Esti-

TABLE XVII

Relation between Annual per Capita Cost of Public Fire Hydrant Service and Corresponding Cost per Hydrant under Conditions Prevailing in the United States

GROUP	AGGREGATE POPULATION IN GROUP	MILES OF PIPE		NUMBER OF HYDRANTS			ASSUMING PER CAPITA COST OF FIRE PROTECTION SERVICE OF	CORRESPONDING ANNUAL COST PER HYDRANT
		Total	Per 1000 population	Total	Per mile of pipe	Per 1000 population		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
I Up to 300,000	12,375,463	12,287	1.00	133,068	10.6	10.8	$0.60	$56
II 100,000–300,000	3,285,351	4,842	1.47	58,053	12.0	17.7	0.75	42
III 50,000–100,000	2,364,110	3,470	1.47	40,865	11.8	17.3	1.00	58
IV 30,000–50,000	1,543,286	3,872	1.86	34,700	12.1	22.5	1.25	55
Average*	19,568,210	23,471	1.20	266,686	11.3	13.7	$0.75	$55
Average of four groups as units			1.45		11.6	17.1	$0.90	$52

Columns 1 to 7 inclusive based upon United States Census Bureau of Statistics of Cities for 1907; Columns 8 and 9 by the authors.
Based upon grand total population.

mated Value of (Water) Service to City" constituting a part of the estimated gross annual income, of the following figures:

CENTS PER CAPITA	RANGE OF POPULATION OF
cents	
44	300,000 and over
46	100,000 to 300,000
48	50,000 to 100,000
50	30,000 to 50,000

The indications point clearly to the fact that this allowance is *not* adequate to provide sufficient margin to cover the fixed, as well as the operating charges, even in the case of our largest cities.

NEED OF INQUIRING INTO NUMBER OF HYDRANT NOZZLES

Attention is called to the need of inquiring into the number of hydrant nozzles as well as the number of hydrants attached to the distribution pipe system. Point is given to this fact in the excellent tabulation, now unfortunately out of date, made by Mr. Dexter Brackett, Chief Engineer, Metropolitan Water and Sewerage Board, of the number of hydrants and fire reservoirs in use in different cities, together with the total number of hydrant nozzles and hose connections per mile of Pipe in different cities in the United States (*17th Annual Report of the Boston Water Board*, January 31, 1893). In this it appears, for instance, that while Chicago had 9.9 hydrants per mile of distribution system, as against 11.5 in Boston, the number of hose connections per mile of pipe was but 19.4 as against 35.8 in Boston.

VALUE OF FIRE PROTECTION SERVICE

It is exceedingly difficult, if not impossible, to get accurate information concerning the amount of insurance risks carried and premiums paid in any community, from which their relation to the assessed valuation can be determined. It is doubtful even if insurance men have comprehensive figures of this sort, and it may at least be said that the writers have been informed by insurance men that they neither had such data nor knew where they could be obtained.

As bearing upon this subject, however, the writers have obtained the data shown in Table XVIII, following, for the State of Massachusetts, from the Commissioner of Insurance. This table shows that in the State of Massachusetts, according to the Fire Commissioner's annual reports for the years 1906, 1907 and 1908, the average

Percentage of Different Sizes of Pipe Used, January, 1892. (Report of Dexter Brackett, Boston Water Board, 17th Annual Report, January 31, 1893)

	3-in.	4-in.	4½-in.	6-in.	8-in.	10-in.	12-in.	14-in.	15-in.	16-in.	18-in.	20-in.	24-in.	30-in.	36-in.	40-in.	42-in.	46 in.	in.	PERCENTAGE LESS THAN 6-in.	PERCENTAGE LESS THAN 8-in.
New York		0.9		61.6		0.2	24.6			0.5		5.5	0.3	1.2	3.1				2.1	0.9	62.5
Chicago	0.3	16.9		48.2	20.1	0.4	6.5	0.3		3.1		0.1	2.8	0.1	1.2					17.2	65.4
Philadelphia																					
Brooklyn		0.2		63.6	17.3		8.0			0.4		4.4		1.4	2.0				2.7	0.2	63.8
St. Louis	3.2	0.5		65.0	2.9	2.7	11.1		2.8			7.0		1.9	2.9					3.7	68.7
Boston		4.7		42.0	11.6	1.6	28.6			2.6		2.2	2.1	2.1	0.8	0.8			0.9	4.7	46.7
Baltimore	25.8	30.1	3.3	15.3	1.5	8.5	2.8			1.7	0.3	5.2		2.5	1.2	1.8				55.9	74.5
Cincinnati	3.9	32.4		30.4	4.5	16.1	1.4			2.2		6.3	0.4	0.1	1.7	0.2		0.2	0.1	36.3	66.7
Cleveland	0.8	7.2		56.2	17.4	6.5	1.7			1.6		1.0	0.9	4.3	2.4					8.0	64.2
Pittsburgh		23.9		43.9	10.8	2.7	4.8	0.1	3.2	0.5		3.7	0.8	2.4	2.9				0.3	23.9	67.8
Washington	2.6	11.4		67 7	0.5	1.1	6.9					1.8	0.2	3.0	2.1				2.7	14.0	81.7
Detroit	4.0	38.3		34.4	9.1	4.7	0.2			1.2			3.5	2.4			2.2			42.3	76.7

Miles of Pipe of Different Sizes in Use in Some of the Large Cities of the United States, January, 1892. (Report of Dexter Brackett, Boston Water Board, 17th Annual Report, January 31, 1893.)

	3-in.	4-in.	4½-in.	6-in.	8-in.	10-in.	12-in.	14-in.	15-in.	16-in.	18-in.	20-in.	24-in.	30-in.	36-in.	40-in.	42-in.	46-in.	48-in.	TOTAL MILES
New York		6 2		422 6		1 2	168 4			3 2		37 9	2 2	7 9	21 6				14 3	685 5
Chicago	3 2	203 9		580 8	242 1	5 1	78 9	3 3		36 8		1 7	33 9	1 0	14 3				0 3	1205 3
Philadelphia																				1001 6
Brooklyn		0 7		286 3	77 9		35 9			2 1		19 7		6 4	8 9				12 1	450 0
St. Louis	11 9	1 9		239 1	10 5	9 8	40 9		10 2			25 8		7 1	10 6				0 2	368 0
Boston*		24 0		216 0	59 5	8 3	147 0			13 2		11 3	11 0	10 9	4 0	4 4			4 8	514 4
Baltimore	108 7	126 6	13 8	64 2	6 3	35 8	11 7			7 2	1 2	22 1		10 5	5 3	7 4				420 7
Cincinnati	11 1	91 7		85 9	12 6	45 6	3 9			6 3		17 9	1 2	0 1	4 8	0 7		0 7	0 1	282 6
Cleveland	2 7	23 9		187 4	58 0	21 6	5 7			5 4		3 3	2 9	14 5	7 9					333 3
Pittsburgh		52 0		95 6	23 4	6 0	10 6	0 3	7 0	1 0		8 0	1 8	5 2	6 3				0 7	217 9
Washington	5 5	24 0		142 0	1 1	2 3	14 5					3 8	0 5	6 2	4 3				5 6	209 8
Detroit	15 9	150 3		135 1	35 8	18 3	0 7			4 9		0 1	13 9	9 3	0 1		8 5			392 9

* These figures are for January, 1892, to compare with data from other cities.

TABLE XVIII

Fire Insurance Data for Massachusetts. Data Principally from Reports of Massachusetts Insurance Commissioner

	1906	1907	1908	1909	1910	1911
From Insurance Commissioner's Summary:						
Risks *written* during year, in Massachusetts*	$1,721,718,455	$1,785,837,938	$1,783,510,300	$1,854,715,897		
Premiums received on same	16,424,434	16,987,131	17,290,365	18,284,486		
Per cent premiums to risks	0.96%	0.95%	0.97%	0.99%		
Losses paid	4,956,371	7,729,583	15,365,119	7,090,966		
Losses actually incurred	5,518,035	7,303,007	15,562,591	7,238,982		
Per cent losses incurred to risks written	0.34%	0.41%	0.88%	0.39%		
From Fire Marshal's Report to Insurance Commissioner:						
Total number of fires in year in Massachusetts	4822	5794	6323	6099		
Total value of property involved	$144,588,140	$156,789,376	$134,313,037	$126,651,117		
Buildings	76,357,491=53%		74,876,632=56%	63,773,039=50%		
Contents	68,230,649=47%		59,436,405=44%	62,878,078=50%		
Total insurance thereon	$115,230,599	$130,244,032	$117,031,388	$116,873,804		
Buildings	60,524,825=53%		65,505,099=56%	61,253,122=52%		
Contents	54,705,774=47%		51,526,289=44%	55,620,682=48%		
Total loss thereon	$6,081,176	$7,962,775	$21,638,867	$8,504,475		
Buildings	2,850,615=47%		9,500,958=45%	4,057,460=48%		
Contents	3,230,561=53%		12,137,909=55%	4,447,015=52%		
Total insurance loss thereon	$5,195,978	$6,630,326	$16,341,836†	$6,755,684		
Buildings	2,447,154=47%		8,361,478=51%	3,272,294=48%		
Contents	2,748,824=53%		7,980,358=49%	3,483,390=52%		

From opposites of polls, property and taxes					
Total assessed value of buildings for state	$1,349,578,702	$1,393,725,486	$1,444,463,558	$1,491,164,428	$1,547,963,769
Per cent of fire insurance premiums covering buildings and contents) to assessed val. buildings	1 2276	1 2276	1 2976	1 2276	
Populations	3,076,227	3,148,774	3,221,321	3,293,868	3,366,415
Premiums per 1000 population	$5340	$5400	$5370	$5550	
Tot. [illegible] per capita	$1.98		$6.72	$2.58	

* Not total insurance in force, which is probably considerably greater.

† Including Chelsea fire.

ratio of premiums received to fire risks written during those years, was about 1 per cent. It should be noted, however, that the risks actually carried by the insurance companies must exceed the risks written in any one year by a considerable amount, for the reason that many of the risks are written for periods of from three to five years.

In Table XIX following have been summarized the risks carried and the premiums and losses paid by the five largest fire insurance companies in this country, and by the local insurance companies of Pittsburg. From this it will be seen that the ratio of premiums paid to the risks carried was, in the companies stated, five-eighths of 1 per cent.

TABLE XIX

Pennsylvania Water Company. Fire Insurance Data for Year 1908. Based upon "The Standard Fire Insurance Tables, 1899–1909." Standard Publishing Co., No. 93 Broad St., Boston, Mass.

NAME OF INSURANCE COMPANY	AMOUNT AT RISK	NET PREMIUMS PAID		LOSSES PAID		Per Cent of Premium	
		Amount	Percent of Risk	Amount	Percent of Risk	1908	Average 10 Years 1899–1909
Five Largest Companies							
Aetna	$985,185,793	$6,948,256	0.71	$3,761,314	0.38	54.1	57.7
Continental	1,290,961,138	6,520,799	0.51	3,203,192	0.25	49.1	52.3
Hartford	1,934,552,768	14,071,456	0.73	7,828,360	0.40	55.6	60.2
Home	1,733,260,335	10,394,058	0.60	5,363,533	0.31	51.6	53.5
German American, N. Y.	1,284,581,944	6,836,780	0.53	3,715,729	0.29	54.3	55.4
Totals	$7,228,541,978	$44,771,349		$23,872,128			
Average			0.62		0.33	52.3	55.8
Pittsburgh Companies, Year 1908							
Allegheny	$3,420,887	$40,209	1.17	$58,866	1.72	146.4	
Ben Franklin	66,809,639	486,212	0.73	266,388	0.40	54.7	
Birmingham	10,555,974	60,268	0.57	21,640	0.20	35.9	
City	3,549,021	15,596	0.44	4,280	0.12	27.4	
German	98,780,749	733,296	0.74	447,409	0.45	58.2	
German American	19,425,706	160,021	0.82	91,701	0.47	57.3	
Humboldt	69,708,747	433,398	0.62	156,454	0.22	36.1	
Monongahela	9,600,395	101,085	1.05	55,024	0.57	54.4	
National	121,868,500	703,291	0.58	252,106	0.21	35.8	
National Union	210,172,166	1,556,974	0.74	966,779	0.46	62.1	
Pittsburgh	17,005,272	138,191	0.81	88,445	0.52	64.0	
Pittsburgh Underwriters	424,120,993	2,791,589	0.66	1,196,625	0.28	42.8	
Union	8,700,857	69,897	0.80	35,676	0.41	51.0	
Western	70,908,971	507,305	0.72	266,965	0 38	52.6	
Totals	$1,134,627,877	$7,797,332		$3,908,358			
Average			0.69		0.34	50.1	

The fire losses in greater New York between the years 1900 and 1905 are shown in the following tabulation:

TABLE XX

Fire Losses in Greater New York, 1900–1905. From Reports of National Board of Fire Underwriters, Committee of Twenty, No. 37 & No. 47, November, 1905 and May, 1906

	MANHATTAN AND BRONX	BROOKLYN AND QUEENS
Period of five years, inclusive	1900–1904	1901–1905
Total number of fires in five years	30,770	16,174
Total insurance involved, buildings	$246,647,155	$92,211,855
Total insurance involved, contents	130,534,761	48,835,793
	$377,208,916	$141,047,648
Total insurance loss, buildings and contents	26,991,900	11,412,493
Percentage of loss to insurance	7.16%	8.08%
Percentage of insurance on contents	38.2 to 79.3%	43.6 to 61.2%
Percentage to insurance on buildings		
Percentage of insurance average	52.9%	52.9%
Average number of fires to 100 population 1 year	2.70	2.14
Average loss per capita and year	$2.45	$1.92

Following are some recent fire insurance data that are of interest in connection with cost of fire protection to water companies. They are taken from the Report of the Superintendent of Insurance of the State of New York, giving fire insurance business done in 1909 in the State of New York, and from the Report of the National Board of Fire Underwriters, May 26, 1910, giving business in the United States in the year 1909.

I. From Report of New York State Superintendent of Insurance for Year 1909

Total amount of fire risks written in 1909	$5,378,756,810.00
Total amount of premium receipts in 1909	43,579,948.00
Total amount of fire losses incurred in 1909	20,427,808.00
Total population of State in 1909, computed from census reports of 1900, 1905 and 1910, approximately	8,900,000.00
Total insurance risk per head of population	604.36
Total insurance premium per head of population	4.90
Total assessed valuation of real estate in State approximately	$10,160,000,000.00

From the above figures, the average rate for fire insurance in the State is 0.81 per cent of the amount of the risk. They are reported by 162 joint stock companies and 7 mutual companies; total 169.

It is also stated by the Superintendent that the great bulk of the fire insurance business is done annually, and that the aggregate of the risks written for a term of years is a small fraction of the total.

II. *From Report of National Board of Fire Underwriters, May 26, 1910*

The average rates charged for fire insurance in the various states by 163 joint stock companies range from a minimum of 0.53 per cent in the District of Columbia, to a maximum of 2.46 per cent in Nevada. They are as follows:

	per cent		*per cent*
Maine	1.48	S. Dakota	1.45
New Hampshire	1.26	Maryland	1.02
Vermont	1.42	Virginia	1.46
Massachusetts	1.00	W. Virginia	1.61
Rhode Island	0.92	N. Carolina	1.16
Connecticut	1.01	Kentucky	1.34
New York	0.81	Tennessee	1.21
New Jersey	0.94		
Pennsylvania	1.10	Nebraska	1.32
Delaware	0.62	Kansas	1.18
		Colorado	1.44
Ohio	1.03	Wyoming	1.99
Indiana	1.15	Idaho	2.51
Illinois	1.24		
Michigan	1.18	S. Carolina	1.27
Wisconsin	0.96	Georgia	1.34
Montana	2.22	Florida	1.87
Utah	1.41	Alabama	1.68
Nevada	2.46	Mississippi	1.82
Oregon	1.63		
Washington	1.72	Louisiana	1.61
		Arkansas	1.65
California	1.69	Oklahoma	1.32
Minnesota	1.41	Texas	1.45
Iowa	1.83	New Mexico	1.83
Missouri	1.06		
N. Dakota	1.76	Arizona	2.38
		Alaska	2.82

The total fire risks written in 1909 by these 163 companies was $33,117,068,129, and the total amount of premiums charged was $371,690,704, thus making the average rate throughout the whole country 1.1223 per cent. It will be noticed that the rates are much lower in the densely populated states than in those having a relatively small population. This is due to the extensive construction of water works and more fire resistant buildings. The risks written

in 1909 in Massachusetts, New York, New Jersey, Pennsylvania, Ohio and Illinois, amounted to 37.6 per cent of the total business, and the amount charged for premiums therein was 32.4 per cent of the total; the average rate being 0.967 per cent. Adding thereto the corresponding figures for Rhode Island, Connecticut, Wisconsin and Missouri, makes for these ten states 43.9 per cent of the total fire risks, 38.0 per cent of the total premiums charged, and an average rate 0.972 per cent charged for the fire insurance.

On comparing this average rate with the rates charged in the younger and less populated states in which water works are not extensively developed, it may be inferred that by the provision of water works a large reduction in fire insurance premiums will be attained.

The same report also contains a record of the number of fires during the year 1909 in cities having populations of 20,000 and upward in the United States, along with the total value of the property involved by such fires and the total fire insurance thereon. From these figures it becomes possible to compute the probable average ratio of the fire risk carried in each city to the value of the property insured. This computation has been carried out for 76 cities in 16 states, as follows: 24 cities in five New England States, 16 cities in the Middle States, 33 cities in Ohio, Indiana, Illinois, Michigan, Wisconsin and Minnesota, and 3 cities in Alabama.

Grouped according to population the results are:

For 45 cities ranging from 20,000 to 60,000 population, ratio = 0.640.
For 29 cities ranging from 60,100 to 500,000 population, ratio = 0.752.
For 2 cities of more than 1,400,000 population, ratio = 0.983.
For 76 cities ranging from 20,000 to 1,793,000 population, ratio = 0.808.

These average ratios are interesting as they show that in cities of less than 60,000 inhabitants, fire insurance is carried to only about two-thirds of the value of the property (buildings and contents); in larger cities about three-fourths of the total value of the property is covered; and in the largest cities (Philadelphia and Brooklyn) nearly the full value of the property is covered. In each class of cities, however, the ratio varies considerably, so that the application of one of these mean ratios to a particular city may result in an error of 10 to 20 per cent in the case of the smaller cities, and reducing as the population increases.

Unfortunately, no extended data are available for showing the

ratio of the total fire insurance carried and premiums paid in a city to its assessed valuation.

A few instances of reduction of fire insurance rates following the establishment of efficient municipal water works have been collected. In the city of Rochester, N. Y., a reduction of about 33 per cent was obtained in 1876; and as it was found that the loss by fire during the next succeeding six years was only a small fraction of the amount of insurance carried, the latter was largely reduced, thereby making the total yearly premiums paid less than one-half of the amount formerly paid for the same valuation. After this time the fire insurance companies declined to impart any further information about their business in the city.

In volume 22 (1908), p. 322, of the *Journal of the New England Water Works Association*, Mr. Frank A. Barbour, C.E., cites three cities in which reductions of insurance rates were attained by substantial improvements of the existing water works, viz: St. John, N. B., where a reduction of twenty-five cents in the rate on mercantile property was granted, thereby effecting a yearly saving of more than $30,000; Fredericton, N. B., where the reduction in rates amounted to about $6000 per year; and Attleboro, Mass., where mercantile rate of insurance was reduced 10 per cent.

In volume 38 (1897), p. 22, of the *Transactions of the Am. Soc. C. E.*, Mr. L. L. Tribus, C.E., states that in several municipalities where he was constructing water works, the fire insurance companies promised to reduce the rates from 15 to 30 per cent after the works were in satisfactory operation; but they did not keep their word fully, and granted a reduction of from 10 to 20 per cent with reluctance.

To show the saving in fire loss that may be expected in a city having efficient water works, reference may be made to the figures relating to Columbus, O., given on p. 26 of Fanning's *Treatise on Water Supply Engineering*. During the four years (1867–1870) preceding the construction of the public water works, the average yearly loss by fire was 0.65 per cent of the assessed valuation, while during the four years (1871-74) after the completion of the works it was 0.13 per cent, and in the fifth year (1875) it was 0.11 per cent of the assessed valuation. The saving in fire loss in five years was thus more than the entire cost of the works.

The Massachusetts records indicate that the ratio of fire insurance premiums covering both buildings and contents, to the assessed valuations of buildings alone, is approximately 1.22 per cent and

that the premiums written average approximately $5400 per 1000 of population, or $5.40 per capita annually; the New York records indicate an average of $4.90 per capita.

The writers are advised by insurance men who have been consulted, that the introduction of a water works system into a community will effect a saving *to the insured* of at least 25 per cent to 33 per cent in his insurance rate upon buildings and contents. Or in other words, that the rate of $1.25 per $100 of insurance would be reduced to at least $1.00 and a rate of $1.00 to approximately 75 cents, by the introduction of a system of reasonably efficient water works. Furthermore, it is asserted that the saving *to the insurance company* by such introduction of water works is undoubtedly much greater than the reduction in premium allowed to the insured cited above.

It is also stated that with the stock fire insurance companies in New England, the prevailing average insurance rates in cities having a good water supply increase from one-fourth to one-third per cent when the distance between hydrants is greater than 500 feet; that upon factory property, the increase is one-half, more or less, and upon mercantile property, it may be two or three-fold.

Reduced to its simplest terms, this would seem to mean that in Massachusetts where the premiums amount to approximately $5400 per 1000 of population, and the total premiums in force may amount to a considerably greater sum, the following per capita savings might result from the stated reduction in insurance rates.

TABLE XXI

WITH REDUCTION IN INSURANCE RATE OF	CORRESPONDING SAVING IN INSURANCE PREMIUMS PER CAPITA ANNUALLY
per cent	
20	$1.08
25	1.35
33	1.80
50	2.70

In discussing any assumed hydrant rental for a given situation, it might therefore be helpful to prepare a tabulation along the following lines; showing the saving in annual insurance premiums resulting from certain reductions in rates figured upon several different amounts assumed to represent the total amount of insured risks:

TABLE XXII

Saving in Annual Insurance Premiums

ASSUMING REDUCTION IN RATE PER $100 OF	ASSUMING TOTAL INSURANCE RISKS OF $.....
	Resulting total saving in annual insurance premiums
$0.20	$.....
0.30	.....
0.40	.....
0.50	.....

ACTUAL AND DESIRABLE NUMBER OF HYDRANTS

In Table XXIII following (reproduced through the courtesy of the Indianapolis Water Company) is shown the approximate number of feet of water pipe per hydrant in different cities in the United States, the average being 555 feet excluding Indianapolis, or 558 feet including Indianapolis. The latter corresponds to approximately 9.5 hydrants per mile of pipe line.

TABLE XXIII

Number of Feet of Pipe to Each Fire Hydrant in Various Cities of the United States. (By Courtesy of the Indianapolis Water Co., 1909)

CITY	POPULATION ACCORDING TO GOVERNMENT ESTIMATE OF 1906	MILEAGE OF MAINS	NUMBER OF FIRE HYDRANTS	NUMBER OF FEET OF PIPE TO FIRE HYDRANTS
Denver, Colo	151,920	500	3,200	790
Wilmington, Del	85,140	119	882	710
Atlanta, Ga	104,984	180	1,668	570
Augusta, Ga	43,125	60	750	420
Savannah, Ga	68,596	67	663	540
Aurora, Ill	26,823	59	499	620
Chicago, Ill	2,049,185	2,073	21,183	516
Decatur, Ill	24,727	45	465	511
Peoria, Ill	66,365	100	1,200	440
Terre Haute, Ind	52,805	70	928	398
Burlington, Iowa	25,741	32	335	505
Davenport, Iowa	40,706	75	668	590
Des Moines, Iowa	78,323	130	1,400	490
Kansas City, Kan	77,912	58	464	660
Paducah, Ky	30,329	36	424	448
Orange, N. J	26,493	40	400	528

TABLE XXIII.—Continued.

CITY	POPULATION ACCORDING TO GOVERNMENT ESTIMATE OF 1906	MILEAGE OF MAINS	NUMBER OF FIRE HYDRANTS	NUMBER OF FEET OF PIPE TO EACH HYDRANT
Paterson, N. J	112,801	125	1,337	493
Auburn, N. Y	32,963	70	600	616
Binghamton, N. Y	43,785	80	800	566
Buffalo, N. Y	381,819	516	4,891	557
Gloversville, N. Y	18,624	33	289	603
Rochester, N. Y	185,703	325	3,500	490
Schenectady, N. Y	61,919	176	2,769	299
Troy, N. Y	76,513	104	1,024	536
Yonkers, N. Y	64,110	103	1,111	490
Cleveland, O	460,327	676	7,966	448
Columbus, O	145,414	210	1,740	630
Dayton, O	106,799	152	1,527	525
Hamilton, O	27,670	43	425	534
Toledo, O	159,980	215	1,650	688
Allegheny, Pa	145,240	200	1,789	590
Philadelphia, Pa	1,441,735	1,500	14,311	552
Pittsburgh, Pa	375,082	402	3,753	565
Reading, Pa	91,141	109	909	633
Boston, Mass	602,278	743	7,772	505
Fall River, Mass	105,942	101	1,153	462
Cambridge, Mass	98,544	128	1,046	646
Holyoke, Mass	50,778	82	659	657
Lowell, Mass	95,173	140	1,271	581
Lynn, Mass	78,743	138	825	883
New Bedford, Mass	76,746	106	1,105	508
Somerville, Mass	70,798	91	1,018	472
Springfield, Mass	75,836	156	1,174	701
Taunton, Mass	30,953	82	877	494
Detroit, Mich	353,535	709	4,752	790
Grand Rapids, Mich	99,794	165	1,547	563
Jackson, Mich	25,360	72	600	633
Minneapolis, Minn	273,825	342	3,893	464
St. Paul, Minn	203,815	285	2,658	566
Kansas City, Mo	182,376	342	4,024	448
St. Joseph, Mo	118,094	115	895	678
St. Louis, Mo	649,320	813	9,298	462
Lincoln, Neb	48,232	67	568	623
Omaha, Neb	124,167	245	1,901	667
Atlantic City, N. J	33,544	65	676	501
Jersey City, N. J	237,952	224	2,331	508
Woonsocket, R. I	42,894	53	624	441
Charleston, S. C	56,317	59	665	510
Nashville, Tenn	84,703	110	931	624
Dallas, Texas	52,796	100	800	660
Galveston, Texas	34,355	31	400	456
Ft. Worth, Texas	27,096	85	876	510
Average of 62 cities	174,355	244	2,257	555
Indianapolis	219,154	293	2,394	574
Average of 63 cities	175,646	232	2,258	558

Broadly speaking, it may be said that the tendency at the present time is to reduce the hydrant interval, or increase the number of hydrants per mile, in the interest of decreasing the amount of hose

required and correspondingly increasing the efficiency of the fire protection service.

It will also be found helpful to consider the number of hydrants that can be massed upon any assumed fire in different districts in the city, such as the congested value district, the ordinary commercial or mercantile district, the residential and tenement house districts, etc. The area to be served by the hydrants will vary from one acre per hydrant in the mercantile and manufacturing districts of highest value, to three acres, more or less, per hydrant in the well built-up residential districts. In the following table, XXIIIa, are shown the areas served by hydrants in the different districts, the average number of hydrants per mile of distribution main, and the percentage of the different sizes of pipes in the distribution system for three typical cities in six different groups, the populations of which cities range from 5,000 to 300,000. These statistics have been worked up from the reports of the National Board of Fire Underwriters, which have been published from time to time during the last five years.

Therefore, in discussing any particular case, the following tabulations will be found suggestive—different aggregate hydrant service payments being assumed as shown in columns 4, 5, and 6 in Table XXV.

TABLE XXIV

1. Approximate miles of pipe distribution systems.
2. Number of hydrants.
3. Hydrant interval, in feet.
4. Number of hydrants per mile of pipe.
5. Required number of hydrants at

a. 7 per mile=755 feet average length of distribution pipe per hydrant.
b. 8 per mile=660 feet average length of distribution pipe per hydrant.
c. 9 per mile=587 feet average length of distribution pipe per hydrant.
d. 10 per mile=528 feet average length of distribution pipe per hydrant.
e. 11 per mile=480 feet average length of distribution pipe per hydrant.
f. 12 per mile=440 feet average length of distribution pipe per hydrant.

TABLE XXV

TOTAL NUMBER OF HYDRANTS	NUMBER OF HYDRANTS PER MILE	HYDRANT INTERVAL IN FEET	RATES PER HYDRANT RESULTING FROM ASSUMPTION OF TOTAL FIRE HYDRANT RENTAL FOR ANY DISTRICT OF		
(1)	(2)	(3)	(4)	(5)	(6)
At present			$.....	$.....	$.....
Assumed			.....	.....	.....
Assumed			.....	.....	.....
Assumed			.....	.....	.....

TABLE XXIIIa

Data Relating to Water Works Pipe Distribution Systems and Distance between Hydrants, and Areas Served for Groups of Typical Cities in the U. S. (From Reports Nat'l Board of Fire Underwriters, 1905-1910)

	300,000 GROUP			200,000 GROUP			100,000 GROUP			50,000 GROUP			20,000–30,000 GROUP			5,000–10,000 GROUP		
	Minneapolis, Minn.	New Orleans, La.	Washington, D. C.	Providence, R. I.	Kansas City	Louisville, Ky.	Portland, Ore.	Dayton, Ohio	Albany, N. Y.	Norfolk, Va.	Lancaster, Pa.	Lincoln, Neb.	Great Falls, Mo.	Vicksburg, Miss.	Burlington, Vt.	Bakersfield, Cal.	Rome, Ga.	Marblehead, Mass.
Date of report	1907	1909	1905	1904	1907	1906	1908	1909	1904	1904	1909	1907	1910	1905	1907	1905	1907	1907
Population, 1910, at date of report	285,000	360,000	322,000	193,000	250,000	235,000	141,000	106,000	98,000	48,000	50,000	50,000	22,000	18,000	22,000	7,500	12,000	7,586
Area, total, square miles	53 0	196 0	70 (Dist. of Columbia)	18 29	26.2		39.0	12 22	11.24	4 5	4.0	7.4		1.60		3 94		
Area occupied		18 0	16 4				13.5	9 00			3.0			1.31		1 20		
Miles of distribution mains, 3 inches and larger	356 03	484 77	420 84	300 04	322.82	277.77	173.81	164 14	118.41	59 01	54 49	62.6		15 97	38.0	13.40	12 9	31 73
Per cent of 3 inches			3 03			0.8			4 23	16 2					19.8			
Per cent of 4 inches		31.8	6 20		8.0	22 3	21.14	16.3	27 88	26.5	27.1	21.4	3.0	3.0		40 6	48.9	3 5
Per cent of 6 inches	56 6	45.9	67.30	69.0	54.0	51 1	42.72	50 1	35.61	38 2	47.6	63.1	75.0	83.8	45 7	59 4	32.6	42 5
Per cent of 8 inches	16 2	2 0	3 04	14.0	17.0	8.8	7.51	12.7	7.95	2 3	10.6	4.6	12.0	5.2	11.6		7.7	31 5
Per cent of 10 inches	0.8		0 44	1.0	7.0	0.8	7.52	13 5	2.55	1.4	4.4	4.0	3.0		17.6		4.6	15 4
Per cent of 12 inches	12.8	11.8	0.62	6.0	6.0	3.6	2.66	4.8	13.46	13.7	4.9	5.3	5 0		2 1			3 7
Per cent of 14 inches					1.0 (15")		4.20	0 6							0.3			3 4
Per cent of 16 inches	5.5	2.1	0.11	2.0	3.0	3.4	2.28	1 2	4.58	1 7	2.5	1.6	2 0	9 0	1.6		6 2	
Per cent of 18 inches							0.73											
Per cent of 20 inches	0.1	3.6	2.04	1.0	2.0	3.8	2.86	0 8	2.16		2.9	1 0			0 8			
Per cent of 24 inches	5.4	1.2	0.97	2.0	1 0	0 5	5.41		1.38						0 5			
Per cent of 30 inches	0.5	0.9	2.04	4.0	1.0	1 9	2 97		0 20									
Per cent of 36 inches, 40 inches and 42 inches	1.2	0.2	2 55	1 0		0.8												
Per cent of 48 inches and larger	0.9	0.5	1.66			2 2												
Distribution mains smaller than 3 inches										1 59								
Total, all sizes										60.70					13.4			
Number of hydrants	3993	4629	2208	1987	4027 (public and private)	748	879	1695	848	249	583	575	340	129	181	87	123 (estimated)	235
Average hydrants per mile of 3 inches and larger	11.2	9.6	5.2	6.6	12.5	2.7	5.1	9.7	7.2	4.2	10.7	9.2		8.1	4.8	6.5	10.5	10.8
Average hydrants, all sizes										4.1								
Distribution of hydrants.																		
Congested District — Average distance between hydrants, feet	220	170			110	246	198	240	320		300	330		420	280			
Congested District — Average area served per hydrant, square feet	80,000	45,000			35,400	71,000	58,800	82,000	50,500		63,000	109,000		165,000	136,000			
Mercantile District — Average distance apart		225							320	300			245			420	380	330 thickly
Mercantile District — Average area served		65,700							80,800				68,500			118,000	110,000	93,000 settled
Manufacturing District — Average distance apart							450											
Manufacturing District — Average area served							219,100											
Warehouse District — Average distance apart							410											
Warehouse District — Average area served																		
Lumber District — Average distance apart																		
Lumber District — Average area served																		
Tenement District — Average distance apart																		
Tenement District — Average area served																		
Residence District — Average distance apart	300	290-340			380	506	W. side–E. side 413 730	376	405	550	320	470	415		560			500 thinly settled
Residence District — Average area served	120,000	107,000–136,000			112,000	210,000	154,200–421,000	109,700	105,000		95,000	207,000	172,000		240,000			
Entire City — Average distance apart														485 ex. mercantile		660 ex. mercantile		
Entire City — Average area served														205,000				

Limitation in Number of Hydrants Undesirable.—The limiting of the number of hydrants which may be attached to the mains is, to say the least, unfortunate, except for the fact that increased number of connections with the mains carries with it some additional danger of injury and leakage and some added cost in construction and maintenance. Nevertheless, the community should be encouraged to place the hydrants close together rather than far apart—150 to 250 feet apart in important thickly built-up districts; and 300 to 500 feet apart in residential districts, with houses well separated; all depending upon the character of the fire risk and values involved. Even if the city is called upon to bear the added expense of making the installation, the saving to it in better service and in fire hose, more than offsets the expense involved.

While the provision contained in the majority of contracts providing for the installation of additional hydrants for each unit of extension of the pipe system (be such unit 500 feet or less) with added annual payment of hydrant rental by the city thereafter, is in many respects satisfactory and equitable, the writers are of the opinion that a better basis of determining the annual charge or payment for public fire hydrant service can be had.

Views of the Engineers of the Committee on Fire Prevention, of the National Board of Fire Underwriters.—Recognizing the admirable work of investigation in the inspection of the water works systems and fire departments of the leading cities of the United States, done during the past decade by the National Board of Fire Underwriters, the writers asked for a brief expression of views of the Chief Engineer of this Board, Mr. George W. Booth. This, he has courteously given:

The engineers of the Committee on Fire Prevention of the National Board of Fire Underwriters, not being concerned with the question of insurance premiums, have not considered the value of hydrant service from this point of view, but rather from that of ability to furnish adequate and effective fire supply. From this latter view point, a rental based on a fixed charge per hydrant has often proved detrimental to good service, since the tendency on the part of the city, where a certain minimum number of hydrants per mile of pipe is specified, is to adhere strictly to this minimum number, regardless of the character of the district to be protected. Some method, equitable to both parties, of computing rental for hydrants in excess of the minimum number, appears to be essential to good service in congested districts. Such hydrants are worth less per hydrant to the city than the absolutely essential minimum number, but they are certainly very valuable, as providing an abundance of water when required and as making the service more effective through the shortening up of hose lines. On the other hand, the cost to the water company of rendering

service to these excess hydrants is much less proportionally, since, except for the cost of the hydrant and its maintenance, the added expense comes about only through the necessity for providing an adequate instead of a doubtfully adequate quantity of water. It may be noted here that there is a pronounced tendency in fire department work towards larger fire engines and heavier streams.

A study of hydrant spacing in most of the large cities of the country has led to the conclusion that the area served per hydrant is a better index of the protection afforded than is the linear spacing, or distance between hydrants. This is so mainly because of the difference in the size and shape of blocks in various cities. An area divided into large blocks will require fewer hydrants to secure a given linear spacing than if the same area is divided into small blocks, even though in the former case the fire hazard and the necessity for good hydrant distribution is greater.

Hydrant Spacing.—The quantity of water required for any district having been fixed upon, proper hydrant distribution may best be determined from a sketch plan of such a number of hose lines as are necessary to care for this quantity; a consideration of friction losses in hose indicates that for anything like effective service no hose line should exceed 600 feet in length if from a fire engine, nor 500 feet if direct from a hydrant, unless the hydrant pressure considerably exceeds that usually found where direct hydrant streams are depended upon. Comparatively few fire departments undertake to place more than one engine, serving an average of two hose lines, at a hydrant or to use more than two direct hydrant streams from each hydrant. Under these conditions, most high value mercantile and manufacturing districts will require at least one hydrant to each 40,000 square feet of area and ordinary well built-up residential districts one hydrant to each 100,000 or 120,000 square feet. As good or better distribution will be found in many of our larger cities, and in the case of mercantile districts corresponds roughly to a linear spacing of 150 feet and in residential districts of 300 feet. For each mercantile block 400 by 300 feet, center to center of streets, there should be at least three hydrants, probably located to the best advantage two at each street intersection and one intermediate hydrant on the long side of the block.

Cost and Maintenance of Steam Fire Engines.—The value to a city of hydrant service depends to a large extent on whether the pressure is such as to furnish direct hydrant streams, or whether fire engines must be depended upon. The cost per year of maintenance of an engine company, including in the latter the accompanying hose wagon and men, over that of a hose company of corresponding strength is about $4,000, including salaries of men, feed for horses, depreciation and repairs, interest, etc.

The cost of a modern steam fire engine of the sizes ordinarily used is $5,000 to $5,500. Most manufacturers rate them by classes, according to capacity, but there is no uniform rule governing this classification. A fair rule for figuring capacity appears to be on the basis of 400 foot piston travel a minute, and the engine is expected to deliver its rated capacity with the pump working against about 100 pounds net water pressure.

Usual Conditions of Fire Engines.—During the past five or six years, practically all of the fire engines in the large cities of the country have been tested by engineers of the National Board, and while the percentage of rated capacity obtained at present is somewhat higher than it was five years ago, it will still

average only about 88 per cent. In some cities, the average has been found to run well over 100 per cent, whereas, in the case of individual engines in other cities, it will be 50 per cent or less. These tests are made under rather more favorable conditions than are likely to obtain during a long continued fire.

Per Capita Maintenance of Fire Departments. The cost of maintaining fire departments will vary greatly with cities of approximately the same population, depending upon whether the department must be maintained on a fire engine basis, upon the extent and hazard of high value districts, and upon topography. As a general statement, efficient fire departments can be maintained at a per capita annual cost of $1.50 to $2.00, exclusive of the interest charges.

THE EFFECT UPON TAXES

It will be found helpful also to study the effect upon taxes of, or the addition to the tax rate resulting from, the assumption of different annual payments for fire protection service in any community. For this purpose the following forms may be of service:

TABLE XXVI

1. Municipality.
2. Taxable Value of Buildings.
3. Total Taxable Values.
4. Actual Hydrant Rental.
5. Taxation Resulting from Assumed Fire Protection Charge, based upon Assessed Valuation:
   - *a*. Annual charge of $.....
     Resulting tax in mills.
   - *b*. Annual charge of $.....
     Resulting tax in mills.
   - *c*. Annual charge of $.
     Resulting tax in mills.

HYDRANT RENTAL AS AN OFFSET TO TAXATION

It was not uncommon, particularly in New England, to find in the contracts of water works corporations furnishing cities with public water supply, a provision making the hydrant rental charge equal to the amount of taxes which might be levied upon the water works property during the life of the contract. It is believed that this practice is undergoing a gradual change. This method had the merit of avoiding any annual controversy over taxes and thus tended toward stability of investment. Moreover, the conditions justifying increase in taxation also imply additional extension of pipe system, which should equitably be followed by increase in hydrant rentals. Fundamentally, however, there is no constant economic relation

between hydrant rental and taxation. Moreover, this method had the disadvantage of tending to limit the number of hydrants put into service, though this difficulty can be overcome by granting the community the right to have any number of additional hydrants desired by it, upon payment of the actual cost of installation and the resulting increased cost of operation, maintenance, depreciation and fixed charges. The greatest disadvantage of this method of payment was, perhaps, that it covered up the real facts, regardless of whether the agreement accrued to the advantage of the city or to the water company, and it may be added that even in cases where the arrangement was an equitable one it often proved distinctly unfortunate in that the public came to believe itself abused, as secrecy and doubt inevitably led to suspicion.

HYDRANT RENTAL AS OFFSET TO FRANCHISE VALUE

This method of compensating for public fire protection service is equally undesirable with that mentioned above. It leaves the assumed values in doubt and, by reason of the reduced rates paid for public service, throws a direct burden upon the individual users of water, through the increased rates which must therefore be collected for domestic and industrial uses.

RELATIVE COST OF DIFFERENT KINDS OF PUBLIC SERVICE

While a comparison on this basis is not of great significance it does serve to bring clearly before the people how relatively small is the amount paid for fire protection service, or indeed for the entire water service, as compared with the payments for police protection, for lighting, or other public service.

A convenient form for such comparison is shown below:

TABLE XXVII

Annual Payments for Public Service

1. Municipality; name of..... ————————
2. Police and Public Safety.....$.....
3. Light .....$.....
4. Fire Protection Service.....$.....

RECAPITULATION AND CONCLUSIONS

1. Public fire hydrant service in the United States is usually paid for upon the basis of an annual rental for each hydrant.

2. These hydrant rentals rarely bear any relation to the cost or the value of the service rendered.

3. They have heretofore usually been determined by average prices paid in the state or surrounding district, in the case of the larger communities, and by the requirement of meeting the interest charges upon the plant investment, in small ones.

4. The range of hydrant rentals paid in the United States is in general from $100 per hydrant per year to a nominal sum of $10 more or less. The average hydrant rental is probably in the neighborhood of $40. Some detailed records thereof appear in Tables I and II.

5. Statistics obtained from 76 American cities supplied by water companies, out of 140 circulars sent, indicate that there has been no substantial decrease in hydrant rentals in the last thirty years, the substantial reductions occurring in only about one third of the cities from which replies were received. The data upon this subject are, however, not sufficiently complete to make general characterization safe.

6. The number of hydrants per mile of distribution pipe system and the corresponding average amount of distribution pipe system per hydrant in 63 different cities in the United States, is shown in Table XXIII, pages 104–105.

	NUMBER OF HYDRANTS PER MILE OF DISTRIBUTION PIPE	AVERAGE AMOUNT OF DISTRIBUTION PIPE PER HYDRANT IN FEET
(1)	(2)	(3)
Average of 63 United States cities	9.5	558
Desirable in heart of large cities	35 to 21	150 to 250
In closely built-up residential sections	26 to 18	200 to 300
In residential districts with houses well separated	18 to 9	300 to 600

The general tendency is to reduce the hydrant interval and this is desirable. No hard and fast rule can, however, be laid down for the proper hydrant interval, local considerations—value of property, character of fire risks, water supply as to the size of mains and quantity and pressure of water available, danger of interruption of service, cost, etc., must control.

A better basis for the consideration of the adequacy of the hydrant installation is perhaps to be had in a study of the area to be served by each hydrant in different parts of the city, the general range of values, under the best modern standards of service, being from one

acre, in the mercantile and manufacturing districts of highest value, to three acres, more or less, per hydrant in the well built-up residential districts.

From an insurance point of view, however, the individual districts should be studied with reference to the number of fire streams which can be massed upon them effectively.

7. The additional cost of installing extra hydrants upon existing mains probably ranges from $50 to $150 per hydrant, the former corresponding to the outlying residential districts with unpaved streets, the latter to conditions existing in the heart of the city where the mains are large. The cost of installing hydrants at the time of building pipe lines is, of course, substantially less.

8. The cost of a modern steam fire engine of the sizes ordinarily used is $5000 to $5500. The cost per year of maintenance of a fire engine company including the attending hose company over that of a hose company of corresponding strength, is about $4000, including operation, maintenance, depreciation and interest charges. The per capita annual maintenance cost is approximately $1.50 to $2.00, exclusive of the interest charges.

The fire engines have been found, recently, to deliver, under average conditions in test, approximately 88 per cent of their rated capacity, the range in individual cases being from well over 100 per cent to less than 50 per cent of the rated capacity; but it is probably fair to say that under actual conditions prevailing during a large fire or conflagration, not more than 75 per cent of the above stated working capacity or two-thirds of the rated capacity, is developed.

9. The danger from serious conflagrations, such as the Boston, Chicago, Baltimore, and San Francisco fires; property and business loss resulting from them, the hazard involved in having so many services of different character, such as domestic and industrial uses, elevators, fire sprinklers, flushing devices, water motors, etc., upon the same main from which the fire hydrants draft their supply, and greater danger of interruption in service for changes in, and repairs upon them; the construction of buildings covering great areas and reaching to great heights, requiring very heavy water pressures; the relatively greater cost of maintaining steam fire engines to do the same work—have led to the introduction of independent high pressure fire protection systems in our largest American cities, having one or more independent sources of water supply readily available at very short notice, in very large quantities and under pressures up to 200 or 300 pounds per square inch.

10. Hydrant rentals, or the demand for public fire protection service, may well be examined from five points of view:

a. The cost of the service.

b. The value of the service.

c. The number of hydrants per mile of pipe and the distance between them, and area served.

d. The rate of taxation corresponding to the amount paid for public hydrant service.

e. The relative cost of other forms of public service, such as lighting and police.

11. The cost of the portion of the water works plant involved by fire hydrant service, probably constitutes from 60 to 80 per cent of the entire cost of the physical property in the case of communities having less than 5000 population, 20 to 30 per cent in communities of 100,000 population more or less, and 10 to 20 per cent more or less in the case of our largest cities.

The approximate annual cost of fire hydrant service is estimated at $1.00 per capita with variations of 40 per cent more or less in different communities, being perhaps from 60 to 75 cents in our largest cities, $1.00 in average cities, $1.25 to $1.75 in our small well served towns and cities (see Table XVI).

These per capita costs of fire hydrant service amount to about $55 per hydrant based upon present practice as to number of hydrants per thousand of population (ranging from 11 to 23 in cities of from above 300,000 population to 30,000 population, and per mile of pipe, ranging from 10.6 to 12.1 in cities of the size first stated), (see Table XVII).

12. Data as to the value of fire protection service are very meagre. It is believed that a reduction in insurance premiums of from 25 to 50 per cent results with the introduction of a good water works system, and that the actual saving is much greater, as based upon the returns made by the Insurance Commissioners in the State of Massachusetts. The saving probably ranges from $1.35 to $3.00 as follows:

WITH A REDUCTION IN INSURANCE RATE OF	THE CORRESPONDING SAVING IN INSURANCE PREMIUMS PER CAPITA ANNUALLY MAY BE APPROXIMATELY
per cent	
20	$1.08
25	1.35
33	1.80
50	2.70

13. The cost of public fire protection service is generally much smaller than that of police and public safety, and public lighting service.

14. The most common method of paying for public fire hydrant service in the United States seems to be by annual rental per hydrant, coupled with the requirement that one additional hydrant shall be ordered in the case of extension of the pipe system, for every 600 feet more or less of such extension.

15. Improvement is suggested along the following lines—Let it be provided that:

a. At stated intervals of say ten years or more, the annual cost of hydrant or fire protection service as then rendered, including in such cost, operation and maintenance charges incurred by the fire hydrant service, and depreciation, interest and profit allowances upon the value of that portion of the water works property necessitated by, or chargeable to it shall be determined. In the latter, allowance for the so-called intangible values, should probably be included in many, if not in all cases. This work should be done by an expert, or board of experts, in water works practice, acting in a purely judicial capacity, regardless of the method of appointment.

b. Additional hydrants may be placed upon the existing water mains, subject to the approval of the water company, or other competent authority, provided an annual rental be paid for each such additional hydrant, which rental will cover the agreed estimated maintenance and depreciation costs, and interest charges involved by the estimated average cost (or varying cost upon a sliding scale covering different conditions, such as size of main, character of excavation, street surface, etc.), of making such installation.

c. The basic amount paid for hydrant rental be increased annually, to cover extensions of pipe system made during the year (upon which extensions hydrants may be placed at an agreed interval of spacing) pro rata in the relation of the extension to the length of the pipe system at the time of the review of the hydrant rental question, or in the ratio of the relative assessed valuations of property as of those dates, or in the ratio of the populations as of those dates, if the latter can be accurately determined, which is not usually the case. If additional hydrants be desired in excess of the agreed number per mile of pipe on extensions, they can be installed upon the basis outlined above in (*b*).

In this manner, it should be possible to adjust the hydrant rental annually, without serious issue and the community will more nearly

bear its just share of the burden, divided between the public, and private, and industrial consumers, than under the present method.

16. The offsetting of taxes, or franchise, by free or reduced cost of hydrant service, is believed to be undesirable. If the community sees fit to make a charge against franchise or other intangible property, it should be made quite independently of the hydrant rental, or fire protection service payment. The company, and the city, are both entitled to know just what burden they have to meet, and to be placed in a position to seek legal redress, in case of injustice or inequitable proceedings. The desirability, or undesirability of franchise tax is not touched upon herein; that question is not here at issue.

17. In conclusion, the writers desire to call particular attention to the admirable reports which have been published by the National Board of Fire Underwriters upon the water works and fire departments of the leading cities of the United States, in which are contained not only many significant and valuable facts, but suggestions of importance to the designer of water works systems.

DISCUSSION

Mr. Metcalf: I do not know that I have very much to add to what was presented to you last night, though there are one or two things which I might perhaps say in regard to this matter.

First and foremost, I would like to say to all of you, that we hope you will not regard this paper as the "last word" on the fire hydrant rental question. We have undertaken to blaze a trail to assist in the work which must follow. We recognize all too well that the data on which some of our conclusions are based are not as satisfactory, nor as broad, or as desirable, as they ought to be, or as they shall be later on.

We hope, however, that we may have set you to thinking. If we shall have set you to thinking on this question and the paper shall serve to that end, we shall say, "good." If it shall serve to induce you to investigate further and help on the good work, we shall say, "better yet." If it shall serve finally to start an era of better practice, that will be best of all; because as we have studied the question more and more we have felt that the practice in this country in this respect was very unfortunate.

Perhaps it ought to be said in connection with this question that an increase in the return for fire hydrant service or fire protection

service does not mean an increase in the gross earnings of water works companies in all cases; for if you get an increased return upon your fire protection service, when you are already earning a fair net return upon your investment, you must expect to make a corresponding reduction in the water rates to consumers. It is after all a question of fair and equitable distribution of the charges rather than a question of increasing the earnings of the works.

One or two other points have been suggested to me as not having been brought out clearly in the paper. One of these is that in the cost of the distribution pipe system, it must be borne in mind that the distribution pipe system of any works is designed not for the present, but for the future needs of the plant; and therefore, in the discussion of any rating problem you must before arriving at your final conclusions, consider whether the plant is what you might term in an over-built condition, in other words, built with an eye to the future rather than to the present needs; whether the plant is in a normal condition where the earnings are reasonable for the character of service rendered; or whether the plant is in an under-built condition where the character of the service is no longer commensurate with the rates, or no longer commensurate with the standard of service that is prevailing or which should prevail in the community under consideration.

It has been also suggested that we have made no reference to water pressures. I think perhaps that is unfortunate, that it would have been desirable to have gone a little further and to have considered the pressures which are maintained upon the pipe systems. These bear directly upon the question of the use of fire engines in addition to the use of the mains and the distribution pipe system. But on the other hand, it is also true that in any community of any size it will be found necessary to have a certain number of men in the fire department to fight the fires, although it is true that an excellent pressure on the water pipe system will result in reducing the number of engines which must be kept in service.

We suggest to you also that it would be desirable, as we view it, for you to get into the habit of thinking of the cost or value of fire protection service in the "per capita" unit rather than in the "per hydrant" unit; and I think if in discussing these matters we make use of that unit, as well as of the hydrant unit, it will be a little more significant. As bearing upon that unit, the figure which we set last night, $1.00 per capita, as perhaps representing average conditions in a community of from 50,000 to 100,000 persons, is easily borne in mind; as is the fact that the variations for communities of other

sizes are 40 per cent more or less from that average figure—the larger rental corresponding to the smaller community; the lower rental corresponding to the larger community.

Mr. Kimball: This paper is an extremely interesting as well as valuable contribution to water works and fire protection literature, covering as it does a field not heretofore reached by any publication within the writer's knowledge. The arguments, particularly for additional or "in between" hydrants, with the accompanying tabulations showing cost, effect upon insurance rates, etc., to say nothing of the self-evident truth that such would materially reduce losses by fire, should be convincing to any reasonable person, while the conclusions to be drawn by a careful study of the paper ought to be of decided advantage.

1. To the property owner, both from his standpoint of possible losses by fire and from that of a taxpayer obliged to meet the costs of fire protection through adequate water supply and fire department.

2. To the underwriters, in assisting in their campaign of education as to the need and comparatively small additional cost of more adequate water supplies and greater number of hydrants.

3. To the owners and managers of water works, public and private, in presenting to them arguments, backed by experience and statistical information which should—much better than the existing "rule of thumb" method of establishing rates and charges for fire hydrants—determine their position in their negotiations with municipalities looking to additional installations of fire hydrants. It ought also to be very effective as an argument for the establishment of adequate water works systems in towns and villages not now having any, and for the rebuilding and enlarging of existing systems not now adequate, even with additional hydrants, for proper fire protection.

The merit of nearly all improvements is gaged practically, sooner or later, by the relation found to exist between their cost and tangible value. It is interesting to consider, by the aid of the tables and facts presented in this paper, how far a community may go, from a purely financial point of view, in lessening the destructive losses due to fires. Fires often wipe out values completely and in this respect are different from nearly all other kinds of losses sustained. Frequently what one loses another gains, at least to some considerable extent, but in case of fire not only is all property that is destroyed gone beyond recovery to anyone, but in nearly all cases there are contingent losses of a nature not measurable by money values and certainly not by any

amount recoverable in the shape of insurance. Losses in business while rebuilding after fire, inability to regain customers, losses of patterns, samples, etc., of which duplicates are not in existence, of books and papers as well as other articles of substantial value to the owner but seldom if ever covered by insurance, and of articles of a personal or sentimental value far beyond the cost of replacement, are some of the considerations which justify substantial investment for fire protection purposes. Insurance, like any other business reflects in its premium charges the cost of the service to a considerable extent and as is not only well known but is set forth very fully in the tabulations in this paper, where the risks are greater, higher rates for insurance prevail. Therefore, when as shown, the returns in fire losses paid back through the agency of insurance are equal to only half the premiums received for such insurance—the balance being consumed by the expenses and profits of the insurance business—it requires no argument to show the benefit received by every taxpayer through adequate fire protection, whether he carries all his own insurance or whether he divides his risks with the insurance companies, for obviously no person can honestly recover through insurance the entire loss entailed to him through fire.

Admitting as we must that all fire losses both direct and indirect ultimately fall upon the property owners as a class and not upon the insurance companies, how much reduction in losses can be obtained by a reasonable investment in better fire protection? Again we find as a concrete example of possible saving, due largely to water works as they now exist, that five states of the Union having probably the largest percentage of property protected by water works, to-wit: Massachusetts, Rhode Island, Connecticut, New York and New Jersey, are shown in the abstract given from the report of the National Board of Fire Underwriters dated May 26, 1910, to pay an average premium for insurance of 0.94 per cent, while three states having probably the lowest percentage of water works protected property, to-wit: Montana, Idaho and Nevada, pay an average premium for insurance of 2.40 per cent. From this can we not safely assume that fire protection in the eastern states, due largely to water works, although fully supported by fire departments, fire proof construction, etc., is responsible for a saving of from $1\frac{1}{4}$ per cent to $1\frac{1}{2}$ per cent on all property insured? Referring to Table XVI of this paper, inferring as it does that the per capita cost of hydrant service including all costs of the water works system due to fire protection is about $1.00, and to the statement that a saving in insurance premiums of 20 per cent

is equivalent to a reduction in premiums paid per capita of approximately $1.08, it can readily be seen that any reasonable expenditure for fire protection, through water works or otherwise, has an immediate return to the taxpayer in reduction in insurance rates, and also carries with it a still further and probably an equal if not greater reduction in fire risks on that portion of the property not covered by insurance.

Again, a substantial and actual saving can be effected by additional hydrants being placed upon existing pipes without other expense than the cost of the hydrants themselves. From Table XXIII covering sixty-three United States cities we find that the average spacing of hydrants is about 558 feet. Properly located, an average of one hydrant to one-half this distance or say 275 to 300 feet apart, would amply cover even an extreme requirement of the underwriters, assuming such hydrants were properly supported by pipes of ample carrying capacity. To set such hydrants would cost perhaps an average of $100 each, upon which amount 10 per cent would be ample to allow for interest and depreciation. Add to this an annual charge of $5 per hydrant for care and maintenance, which is large, and we have a total annual charge of $15 which would safely cover the full costs of such hydrants, which costs, based upon the statistics given of these sixty-three cities would add from twenty-five to thirty cents per capita to the present costs as worked out. This would require an average reduction in insurance premiums of only about 5 per cent to repay to the taxpayers what this very much increased service would cost the community, and this without taking into account the large saving on the uninsured risks, due to the decreased fire hazards. Can it be doubted for a moment that such an installation of "in between" fire hydrants would result in a much larger reduction in insurance rates than 5 per cent? An instance is known to the writer of a rider, called the "pink slip" attached to all insurance policies in certain southern cities, which arbitrarily raised insurance rates 25 per cent, the same to remain until certain increases in the number of hydrants in the business district had been made as well as increases in the number of men and in the apparatus of the fire department. The cost of all these requirements in one town where the details were well known was materially less than would have been the cost of the installation of all the hydrants above noted, and when done was much less efficient in its general results. If therefore it is necessary for the underwriters to affix a penalty of 25 per cent for not doing certain things of less importance, it would seem to be conclusive that much

better results than a 5 per cent reduction in premiums would follow the doubling of the number of fire hydrants upon a given mileage of piping.

The Hon. Walter L. Fisher, Secretary of the Interior, in an address in May of this year before the National Fire Protection Association, stated that the people of this country at large were paying $2.51 per capita for fire waste or losses, and that these losses were equal to one-half the value of all new buildings erected during the same period. His further statement that annually 1,500 persons give up their lives and nearly 6,000 are injured by fires in itself is startling and is sufficient to warrant large expenditures for the prevention of fires.

If proper fire protection through an amply supplied water works system, with hydrants in sufficient numbers to insure plenty of water at the point it is needed and without undue friction loss through long lines of hose, can reduce this property loss even one-third, to say nothing of the saving in human lives and injuries, can it be questioned that any reasonable amount spent for such works and hydrants would effect a saving amounting to several times its cost in insurable property? And in existing works of suitable capacity, the installation of additional hydrants in sufficient numbers to allow of an ample number of fire streams with short hose lines (not exceeding from 300 to 400 feet of hose as a maximum) will in a large degree and in numerous cases result in a saving sufficient to largely if not wholly pay all additional expenses due to such "in between" hydrants, in the purchase and maintenance of hose, maintenance and repairs of steamers through the lesser use required of them when hose directly attached to the hydrants can do the work as well and in the saving in other incidental expenses connected therewith.

Mr. Knowles: Thanks are due the authors, from water works operators, users of water and in fact everyone interested in a square deal, for this timely and important paper. The subject has been so thoroughly investigated and so ably presented that one can attempt to touch only upon a few of the more interesting points which they have brought out.

DISTRIBUTION OF CHARGES

The real problem which underlies this question of reasonable return for fire protection involves, as has been pointed out, a determination of the equitable distribution of the charges for water works

service among the various classes of users. This question, is just as important in municipal works as in those operated by private concerns, or companies for profit.

In Pittsburgh the popular impression prevails that the water works is a paying institution. It is difficult, with present accounting methods, to determine the real facts, but a recent study shows, on the contrary, that the income from water rents is not sufficient to meet all the expenses of maintenance, operation and interest and sinking fund payments on outstanding water bonds and that the deficiency, of about 15 per cent, is made upon the general tax levy. This is, in some respects, as it should be, for there are certain services rendered by the water department, for instance, fire service, water supplied to schools and other institutions of a public character, or that used for street sprinkling and flushing, the cost of which should be a charge upon the entire community. By including a portion of the yearly expenses of the water works in the tax levy, this burden is somewhat distributed among all the taxpayers,—some of whom are non-residents and therefore would escape their just share, were the revenue from water rents sufficient to cover the entire cost of furnishing water.

The important point is this,—that while such division of expense among the water users and the property owners is in line with good practice, there is no certainty that this division is made in a proper or equitable ratio, unless we determine the true value of each service and the cost of supplying it. It may be argued that the problem is largely one of accounting and that the total expense will be the same amount in any case. In answer to this, it is sufficient to say that there is a growing tendency upon the part of the public to insist that every kind of service, whether rendered by the municipality or by a private concern, be made to stand on its own footing; so that the people be not deceived, nor misled and that all items and factors of cost of public service be fully understood.

Already considerable progress has been made in the broad study of the various factors which determine the total income a water works should receive, in order to make the project a paying investment. Many of the elements of rate making, such as proper capitalization, physical valuation, going and development value, depreciation, reasonable return to be allowed, etc., have been extensively investigated and thoroughly studied during the past few years. Before long, some degree of uniformity in the fundamental principles of considering these items may reasonably be expected to result. In the meanwhile, there has also been a tendency, under both private and

public ownership, to apply thorough going accounting methods to water works problems and to readjust the cost of service among the various classes of consumers in such manner that each shall bear its just and equitable share. Large industrial concerns, with many departments and their detailed system of cost accounting, do this most thoroughly. Each is charged with materials and supplies obtained from another and also receives credit for service rendered. It is thoroughly believed that such accouting should be applied to municipal water departments and that, when so applied, no department be permitted to escape its burden of expense by obtaining something without payment, from any other branch of the municipal service.

As an illustration of the present tendencies in this respect, attention may be called to the recent decision of the Wisconsin Railroad Commission in the Madison case. Here the municipality, which owned the water works, was prohibited from furnishing any free water to other departments, or to any institutions. In fact, the use of free water in any manner, shape or form was no longer to be allowed; the city was compelled to charge for it.

PRIVATE FIRE PROTECTION

The authors in their paper make a statement which possibly needs further explanation. It is to the effect that the extra capacity for private fire protection is included within the provision for public protection and therefore no large additional revenue for this private protection can be claimed. At first thought the writer was inclined to take exception to this, but upon further explanation by Mr. Metcalf, he agrees, perhaps not in theory, but at least in practice, with their conclusions. It is now understood that this statement is supposed to refer simply to hydrants and, if so, it is true, provided these yard or factory hydrants are included in the total number of hydrants.

There are many other forms of industrial fire protection, such as sprinkler service, stand pipe systems within the yards, etc., which come under a different classification. Such special service is performed for that particular company, the character of the service differs in many respects from ordinary hydrant installation, it affords much greater protection to the works, secures a lower rate of fire insurance and in other ways possesses advantages which should be paid for by the persons directly benefited. One hears ever ready arguments that the company contributes to the growth of the municipality, is a help to the community and should therefore be fostered by the public.

But, in this day and generation, factories which are worth having in the community are not looking for that sort of "*pap.*" They are beginning to realize the greater influence of living and social conditions upon the employees as affecting their existence as a successful concern. Such an industry appreciates the fact that proper housing conditions, transportation facilities and other factors of like character, which affect the daily life of the workers and their families are more to be desired, even from the purely commercial standpoint, than a reduction in water rates, exemption from taxation, or special privileges of a similar nature. The men at the head of such organizations are beginning to take an interest in the advantages afforded the children of their working men and to inquire into the playground equipment and school facilities provided. I know of an instance where the representatives of the workmen of a concern were sent to investigate a possible location for a large industry and, upon discovering that the living and social environment for the workers would be unsatisfactory, reported the conditions found, with the result that the concern did not locate there. The controlling factors, which will determine the location of industries in the future, are going to be more and more the social, economic and educational facilities afforded workers rather than the financial inducements held out to the manufacturer. We are all willing to pay for what we get, provided we get it.

COST OF OTHER PUBLIC SERVICE

In the last part of the paper, it is stated that the cost of fire protection may well be considered in relation to the payments for taxes and for certain other forms of public service, such as police, health, fire and lighting departments. Such a comparison will operate to cloud the issue, for we are all aware that the cost of public service in these lines varies greatly in different cities, even without any apparent reason. Possibly an exhaustive study of the subject and a careful analysis of the conditions under which each of the departments operates would show these variations in cost to be more apparent than real, but so far as is now known, the cost of these classes of service vary widely, without good reason.

In view of this fact, what is the use of referring to the cost of these other items which do not bear any relation to the cost of fire service and are subject to just as great variations as the item under discussion. The real question to be answered is: what does it cost the municipality or the company to furnish fire protection and what is this protection worth to the community? This is the real issue, not

whether such service is more or less expensive than lighting, police, or any similar service; which already vary for unknown reasons. Such comparisons, do not assist in solving the problem, but, on the other hand, prove a real hindrance to a clear understanding of the facts.

BASIS OF PAYMENT FOR FIRE PROTECTION

It is evident to the thoughtful investigator that the full cost of hydrant service, or public fire protection, as well as other forms of public water service, should be borne by the tax payers of the entire community and not alone by the water rate payers; for otherwise, the non-resident tax payer avoids some share of his public duty. This is equally true, whether the works are owned by the municipality or by a private concern. The total cost of fire service should be determined as a lump sum, sufficient to cover all proper charges, such as interest on investment, depreciation, operation and maintenance, which belong on that portion of the plant used for this service. We get many excellent suggestions from the authors as to how this cost may be determined and assessed. The writer in discussing a paper by Mr. F. V. French, presented to the New England Water Works Association upon April 12, 1911, referred briefly to several of the objections to the common method of paying for fire protection by an annual hydrant rental. The usual lack of a proper distribution and a sufficient number of hydrants was there pointed out and attributed to the present unsatisfactory practice and the customary method of payment. The usual basis of payment for fire service provides an annual rental at so much per hydrant, and the number of hydrants is determined by the choice of the municipality. In making the original contract, a certain minimum number of hydrants has been determined. As the city grew, and most of our cities have grown very rapidly, the contract generally has frequently not been changed, at least so far as the minimum number is concerned. Consequently, the municipality, desiring to keep the price as low as possible, has made an effort to keep the number of hydrants at the minimum.

It seems that the compensation for fire service should be differently arranged than this. Let it be recognized that payment should be based upon the ability of the plant to furnish sufficient water at good pressure and not merely upon the cost of installing and maintaining a certain number of hydrants. The number of hydrants should not be made the basis of payment any more than should the quantity of water consumed for fire purposes be considered as a proper measure

of the fire protection rendered. It is possible and practical to estimate the value of this service in any given case. This cost may be paid in several ways, as a lump sum per mile of main, or in any similar manner which may be thought advisable; but the important point is to have it understood that the real basis of cost is the fire protection afforded and not merely the number of hydrants in use. Then and not until then, will the present incentive to unduly restrict the number of hydrants be removed.

STUDY OF BASIS OF CHARGES

The determination and assessment of such a charge at reasonably frequent intervals, to secure an equitable result, is an important work for thoughtful, fair minded men, well versed in the subject. Partisans representing either the city or the company are not likely to approach the problem from the right point of view. Therefore, the suggestion concerning the necessity of a separate study of each water works system, by "an expert or board of experts in water works practice," is one which will commend itself to those who have given the subject serious thought.

It is not to be expected that matters of such a technical nature can be best decided in the courts, by men whose training has not been such as to prepare them for such work. It would seem that all questions of fact regarding the system, or those of an engineering character, should be referred to an impartial technical tribune as suggested; while the legal phase of the problem should be decided by those versed in law. That the suggestion is a practical one will be evident to those who have followed the numerous cases presented before the various public utilities commissions. It is not claimed that these commissions are infallible, no human tribunal could be, but they certainly have shown a good understanding of the complex problems presented and their decisions appeal to engineers as most fair and practical and the result of painstaking study.

When once determined the agreement may wisely contain a provision, which will cause a review and possible readjustment of the rates in five or ten years, and a further provision which will allow for the growth of the service in the meanwhile. The latter requirement should be alike compulsory upon the water company and the city, and the former to provide mains and an agreed number of hydrants per mile, upon some basis like the percentage growth of population, or the additional mileage of new streets built upon; and upon the city, to pay per

mile of main or per hydrant for additional fire service. By such an arrangement, the service will be automatically maintained at a given standard, during the intervals between periodical adjustments, which latter will be sufficiently frequent to prevent any marked irregularity of rates to arise.

REDUCED INSURANCE RATES

One other thought expressed in the paper is in regard to possible reduction in insurance rates. This subject is far too important to pass over quickly, but perhaps I may offer a suggestion brought to mind by the reference of the authors to the fact that certain insurance companies did not continue to give Rochester the benefit of greater fire protection, or permit the public to have knowledge of what premium reductions were feasible. This illustrates how another side of the water rate question may well come under the control, guidance and direction of public service commissions; viz., the methods, rules and work of the rate making committees of the insurance companies. Nobody seems to know how the regulations and schedules which are in effect and are being maintained by some of these underwriters' committees were ever evolved. The fundamental work and study of the public service commissions is necessary and would be helpful to a clear understanding of such premium rate making, as well as the subject of water rates.

The principle of regulation rather than the older thought of unlimited competition has come to stay, because such service as we are discussing is properly a monopoly. Furthermore the work of such public service bodies should be extended, and the united influence of all interested in the wise development of this country should be constantly exerted along such lines as will keep the control of these commissions free from any suspicion of partisanship or hobby-riding. When the regulation of service performed by water works and the control of rates charged for all service, whether owned by a municipality or a private corporation, shall be brought under the wise control of such a body, a progressive step in advance will have been accomplished.

Mr. Maury: I am at a disadvantage in attempting to say anything about the details of the most valuable paper to which we listened last night. I had not the privilége of reading it in advance; therefore I will not attempt to discuss its many admirable features in detail. The thought that has been uppermost in my mind was that which has

been so briefly and ably presented by Mr. Knowles. We should all recognize the modern tendency toward publicity of accounting. Those of us who have to do with private corporations and public service corporations, and those of us who have to do with municipal public service departments, must recognize that publicity of accounting is an important step in the right direction. We have here a curious condition in the relationship which exists between insurance companies and water departments and the insured. The insured and the insurance company are the beneficiaries as the result of water works extensions for fire protection. The party which spends the money for the extension is the water department, which makes its accounts public. It is compelled to do so, and it should be compelled to do so whether it is a private corporation or a public corporation. In all fairness the two other parties to this three cornered contract should be compelled to make public the benefit that each derives from the extension.

The attitude of the insurance company heretofore has been, "If you do not do so and so, we will raise your rates. If you do do a large number of things, we shall be able to take something off your rates, but if you fail to do any one of this large number of things, our contract does not apply."

We do not know how much they benefit by these improvements; they do not tell us. They ought to tell us; and before such improvements are undertaken a thorough investigation should be made to arrive at reliable figures as to the benefits which are going to result from the improvement requested. One feature of which we are ignorant is in regard to how far it benefits the insurance company; they keep that under their hats. They ought to say in advance what they will do in return for each specific item of improvement, and when the improvements are made the reduction of rates ought then to go into effect. They can tell us whether or not they will do this, and whenever they tell us they will, then we should expect them to make the reduction promised. Then we can at least count on that much in a definite net return on our investment.

I feel with the authors of the paper that there is much more work that can be done in this field, and I should like very much to be assured by the authors that they will not let this matter drop where it is. They have done splendidly so far. The paper is a classic in its line, and will be of very great benefit to the members of our association. It is sure to awaken, when people shall have had a chance to read it and study it, the widest possible discussion. The authors have

said that there are some points which they feel they have not fully covered, and I think that this association ought to request them to give us the benefit of their valuable services in extending at the next convention the work that they have already done, by further contributions to our literature on this subject.

Mr. Chester: The paper is to my mind one of the most useful that has been presented to this or any other convention, or that will grace the pages of our proceedings. It will serve as a valuable reference.

But the authors in compiling this paper made one statement that I think needs emphasis—and I say this without discrediting the paper—namely, that the data accumulated, the tables given and the statements made, can simply serve as a guide under average conditions, and cannot be considered as an absolute rule governing every specific case; each case must be worked out for itself. We can readily see how different cities will necessitate different costs of effecting fire-protection. For instance, take the long cities that we have in our mountainous districts which necessarily are built miles long and feet wide. We cannot provide fire protection for such a city for the same price that we can provide fire protection for a squarely built one.

There should also, I think, be some notice taken as to whether the service is reservoir, or direct pumping. A further difference should also be made as to whether or not in the direct pumping the pressure is increased when the fire bell rings. There is also a vast difference, which has only been touched upon, dependent on whether or not the fire pressure is furnished by the water works or whether it is furnished by fire engines. I think in the latter case it would be well to include in the figures an estimate of the fire equipment necessary where the pressure is not furnished by the water company. There is bound to be a vast difference in the furnishing of one kind of fire protection over the other as affecting the cost for the water works.

Another pertinent question that is touched upon in the paper and was brought out by Mr. Knowles, is I think one of the most important to this body and that is the relations with the underwriters. I have been up against underwriters penalizing rates on fire protection fifty times I expect. I have endeavored many times to have those penalties removed. In all cases we have been able as a general thing to secure a statement of what the penalities were there for, and to secure in many instances recommendations for improvements demanded from the water works; and which if carried out we were led to believe

would remove the penalties; but after the improvements were made, we seldom realize any more than a small reduction in the penalties, equivalent to 25 per cent perhaps.

I believe with Mr. Knowles that the Underwriters' Association is a combination in restraint of trade. I do not believe that I can claim originality for that. Sometime ago in a particular case when we had been annoyed by them to the limit, I took the matter up with Mr. Purdy of the American Guarantee Company, and he said:

> You are up against nothing new. I am of the opinion that the water works interests of this country have got to combine and take that combination into court and have their affairs so adjusted that we will not be dependent upon the judgment, as we are in many cases, of boys just out of school, who recommend things that any engineer would blush to suggest, and certainly would not attempt to formulate as requirements for public fire protection. Not only that, but when we have argued the matter out with the first boy and get him to modify his requirements, and then we carry them out, they send another boy who finds a lot of other things, with the final result that the penalties are not removed, thus putting the water company in a very embarrassing position in its relations with the city.

As regards in-between hydrants, referring to the remarks of Mr. Kimball, I disagree with him in the idea of reducing the per capita charge for hydrants. In-between hydrants in ninety-nine cases out of a hundred are set in congested or business districts and I believe should be charged to the business district, and not per capita over the city borough, or town. I believe that the original distribution of the hydrants throughout residence districts are generally adequate and the in-betweens are made necessary by the growing up of a congested district; therefore the per capita on in-betweens should be charged to the congested district rather than spread over the entire city. I do not believe that we should charge up the entire fire losses upon the mercantile districts to the total distribution. I remember years ago being very much impressed when reading Hawthorne's *Marble Faun* by his impressions of Rome. He thought he saw the need of cities being constructed so that they might be destroyed by fire at least once in fifty years, for purification purposes if nothing else. I do not believe our American cities need purification as much as Rome in Hawthorne's opinion did; but we cannot deplore absolutely and altogether the fire losses that we suffer, for we many times benefit more than we lose. So let us be fair when we get to piling up such losses and at least credit some of the benefits that have accrued.

Mr. Gwinn: It seems to me that it is my duty to express an appreciation in a mild sort of a way of the paper prepared by Mr. Metcalf in conjunction with Messrs Hawley and Kuichling. I think they have given us some very valuable information, in fact it is so valuable that it will probably take rank as a text book. I believe that it will be referred to many times in the future by most of those who are present here today.

One feature of the paper which especially appeals to me is its educational value to citizens who do not make a study of fire protection conditions and who sometimes insist that the fire hydrant is not worth anything, because it is only opened about once a year, and some not even opened that often, hence there should be no charge made for fire hydrants; not realizing the necessity of having large lines of pipe connected with those fire hydrants. For that reason I can see some objections to Mr. Kimballs' plan of not making any charge, or at least pro rata charge, for the additional hydrants that are put in between; because if you establish a large number of hydrants on certain pipes in a certain district, you must of course have a large enough main to supply those additional hydrants.

The question that he raises about franchise taxes not being included in the charge for hydrants, I think is well taken; because I think all these propositions should stand by themselves.

In regard to the insurance side of the case as it has been discussed here this morning, I cannot agree entirely with Mr. Chester. You remember perhaps eight or nine years ago we were discussing this question of fire protection in connection with automatic sprinklers, and Mr. Blauvelt, Mr. Robinson and other prominent insurance men spoke at our sessions, and in the course of the discussions stated that they would furnish me blue prints of underground construction in connection with industrial plants. Two or three years passed by and I had not received them; but I want to say that they did finally come. It is true they came two or three years later—but they finally arrived.

The insurance interests in a certain western city met with the city officials and members of the Commercial Club a few months ago, and they agreed that if the city would spend $150,000 they would make a reduction in insurance rates amounting to $135,000. That is something definite and tangible. Our relations with the Indiana Inspection Bureau and also with the Fire Prevention Committee of the National Board of Fire Underwriters have been very satisfactory indeed. They have always treated us squarely. I will say that in justice to the fire insurance interests.

MR. I. B. BROWN: This is a most decidedly interesting discussion from which we are gleaning much information. We have the delightful knowledge now that in one instance at least the underwriters have made good their word. To me the consensus of opinion among the engineers and the membership in general of this association is of the highest importance to those who are interested in furnishing the public with water and with fire protection. It was stated here, I think, yesterday morning by one of the members of the association that sooner or later in every city in the Union there would be established by law a public utility commission; and that means the supervision of the rates, the supervision of charges, or the establishment of rates which may be charged for the services performed by the water companies.

If this be true, gentlemen, it only accentuates the value of the paper which has been read by Mr. Metcalf. The consensus of opinion of such men as you is the means of molding sentiment and of establishing laws. When a court instructs a jury as to its duties in arriving at results as to questions of fact it is guided very largely by the opinions of experts which are made the basis of the court's instructions to the jury.

Now if we are to be subject to public utility commissions, it is highly important that on conservative lines, on lines that are fair to corporations and on lines that are fair to the public, we shall arrive at a just determination of the question of rates for public services, and especially with rates to be charged to municipalities for hydrant service. I believe that the commercial world is so very largely dependent upon the public functions of water companies that it cannot exist very long without them; and in all these discussions it is proper for us to be so eminently fair to the public that there can be no just criticism made upon the meetings of this organization.

So I desire to emphasize the value of this paper in this way, that it not only gives us knowledge upon which we may predicate our own actions; but such a paper, fortified by facts as it is, must to a very great extent be a guide in establishing the law for interpretation by our courts and the basis on which rates may be established which shall be as fair and uniform as it is possible to make them, applying them to such diversified conditions as exist in the numerous water companies throughout this country.

MR. JORDAN: Personally I thoroughly appreciate the valuable service rendered by Mr. Metcalf and his associates to this organization in preparing this able paper.

I had occasion some two or three years ago to give some consideration to the question of hydrant rental, for the reason that the Commercial Club of our city had conceived the idea that our hydrant rental was rather high, and cited a rental of $10 paid by a Massachusetts town as about the proper charge for our city. We naturally took some interest in the question, and that which most surprised us was the fact that the average citizen apparently takes no further account of hydrant rental than that it should be the average paid by other cities in his locality, overlooking entirely the fact that hydrant rental is governed entirely by the quality of service rendered and by the existing local conditions. After going into the question more carefully, we were able to show the people of our city some good and valid reasons why hydrant rental in Indianapolis should remain at $45 per annum, and it has since remained at that figure.

Some twelve months ago we had in our city a "Pink Slip" agitation. Representatives of the insurance companies came to the city and made some uncomplimentary remarks about our fire department and about our city in general. After giving some thought to the matter business men decided to deviate somewhat from the usual custom in such matters. Mr. Richard Lieber, a member of the Mayor's Advisory Committee, was appointed a committee of one to look into the whole subject, which he consented to do, providing he was given sufficient time to make a very careful investigation. At the end of six months he called a meeting of the interested parties, but to his surprise he was unable to get in touch with the insurance authorities, but after persistent effort a committee appeared who stated that they had sufficient authority to make a reduction as well as an increase in the rates. Mr. Lieber submitted his report, and soon convinced both the insurance representatives and the citizens that he was thoroughly conversant with the subject in hand, and after some consideration the "Pink Slip" was withdrawn. The citizens committee expressed themselves as being thoroughly satisfied with the consideration shown our people by the insurance companies, and it was the unanimous opinion of most of our people that we had been given a square deal.

It occurs to me that few men of our city have rendered our citizens a more valuable service than that rendered by Mr. Lieber, in connection with the insurance subject.

The situation relative to the use and abuse of hydrants has apparently become of serious moment throughout our country. It is to be hoped that this able committee will go a little further in the subject of hydrants and hydrant rentals, and define specifically what con-

stitutes proper use of fire hydrants. In some cities the fire departments become accustomed to good service at the fire hydrant, and in course of time they show a marked tendency to depend almost entirely on the hydrant and overlook the necessity of providing a sufficient number of first class fire engines.

In practically every city complaint is heard about the abuse of the fire hydrant by the other city departments, chiefly the street and sewer flushing department, and this committee would render a valuable service to the water departments if they could in some way make it exceedingly plain that fire hydrants are not the playthings of the irresponsible men of some of the city gangs, but are located for the express purpose of providing fire protection for the citizens of the city.

MR. HAWLEY: I can say "Amen" to all that Mr. Chester has said about insurance underwriters. In the part of the country where I live, the Underwriters' Association issues a little red covered book on *Recommendations for Fire Defenses and Charges to be Made Where Deficiencies Exist*, in which they define the various deficiencies that we have heard so much about. One deficiency which is mentioned in that book is *private ownership of the waterworks*. It reads, "Ownership- if waterworks system not owned, controlled and operated by municipality, charge one to five cents." I am not biased because I happen to be with a private water company at the present time. I have been on both sides of the fence. But I think any fair minded man will realise that an extra charge for insurance because the waterworks is not owned by the municipality is unfair and unreasonable, especially when we consider that some of the municipal water departments are run on a political instead of a business basis.

Twenty-five years ago I had charge of the construction of a little water works plant in a village in this state. Before the plant was built we had the promise of a material reduction in insurance rates. After the plant was finished we got a reduction of about 10 per cent. That has since been increased, so that today they are paying practically the same as they did before, yet the total losses by fire in that town in the whole twenty-five years since the erection of the water works were exceeded in single years a number of times before the water works were built.

I want to emphasize the fact that a charge of so many dollars per year per hydrant is a very bad way to fix the price to be paid for fire protection. It places a premium upon the absolute minimum of fire

protection with which the municipality can get along. It is neither a fair measure of the cost of furnishing fire protection nor of the value of the fire protection to those who receive it.

In addition to that, there should be no free water included in the hydrant rentals. I have known cases where the hydrant rental covered the water for flushing sewers, washing streets, and all that sort of thing. They would "wash the streets" from roof to roof, of opposite buildings, and if the water had actually been measured and paid for at its fair value the bill would have amounted to more than the company was receiving for fire protection. Some other basis must be found. The paper suggests an annual charge of so much per mile plus a charge for each fire hydrant, the rate per fire hydrant in that case being barely sufficient to cover interest, depreciation, maintenance and taxes. In another case I have known of a flat rate being made per year covering the entire existing distribution system, to which rate was added a certain rate per mile of pipe as the system should be extended; allowance being made for the addition of a minimum number of hydrants to every mile of additional pipe; giving to the municipality the right to use as many hydrants as it pleased in addition. In this case the municipality owned, set and maintained the fire hydrants; which I think is a very good proposition. The municipality did not have to pay anything additional for additional fire hydrants, beyond the minimum number per mile. If you are receiving a reasonable return for the fire protection furnished I think that is only fair.

I feel too that if you are receiving an adequate return for furnishing fire protection there is no reason why an additional charge should be made in the case of industrial plants for installing additional fire fighting apparatus, sprinkler systems, hose connections, etc. I agree with Mr. Knowles that there is no direct relation between the cost of furnishing fire protection and that of street lighting, police, health department, etc., but I believe that many times it will be found not only of interest but helpful to compare these costs. I am sure that if Mr. Knowles was endeavoring to secure for a water company a reasonable return for fire protection and if he found, for instance, that they objected strenuously to paying $1200 or $1500 per year for fire protection while at the same time they were paying $2500 or $3000 per year for light, he would feel that he was not getting quite a square deal. I realise that the other services have no direct connection with fire protection, but, at the same time, I think that there is a value in making the comparison.

MR. HATTON: Mr. President and Gentlemen, I did not intend to say anything on this paper; but Mr. Jordan's experience in Indianapolis had brought to my mind a little experience I had not long ago, and has also clearly indicated to me the great value that this paper will be to the practicing engineer as well as the water works superintendent. A brief description of my experience may be of interest to you.

A few months ago I was asked by the legal representative of a capital city of one of our states to come down and help him determine the proper hydrant rental for the city to pay the water company whose franchise had expired, and who had made application for a renewal. With this application the company had insisted upon a higher hydrant rental.

He requested me to be sure and bring down all the data in my possession showing what other cities were paying for fire hydrants. My Indianapolis friends were kind enough to send me the very valuable data which they had prepared upon this subject and which I took with me.

When I got to the city the solicitor, and his colleague, insisted that I should base my judgment upon the rates prevailing in the nearest cities of like size. I rather insisted upon being the final arbitrator before I undertook the work. The city authorities agreed to this, but the water company refused, because, of course, it did not know what method I purposed using to reach a conclusion.

I found the city had been paying a hydrant rental of $10 per year. It had a population of something over 30,000. The water had to be filtered, it being secured from a very turbid source. Before the filter was installed there was so much mud in the pipes that but little pressure could be secured at the hydrants for some time after they were opened, or until the mud had blown out. The city was one of those long, narrow towns, requiring long distribution mains with few services.

It was a great surprise to the legal fraternity that I insisted upon making a partial appraisement of the value of the water plant, and because I started out on the principal that the value of fire protection, or hydrant rentals, should be based upon the value of the cost of that portion of the plant, and its operation, which particularly applied to furnishing that service.

Almost all the data which I had to use in making this appraisal I had to prepare and make up original, right on the ground. It took me four or five days to arrive at a reasonably fair conclusion, which

was that the hydrant rental should be $45 instead of $10. This so pleased the water company, and displeased my clients, that no price has yet been agreed upon, but the water company has regretted that it did not agree to my being the arbitrator.

So much for that. What I want especially to say is that this paper, prepared as it has been in such detail, is of the utmost value to the practicing engineer who does have these situations confronting him time and time again. I have had them arise several times in my practice; but I have never experienced such trouble in getting two parties together as in the instance just referred to, in fact I have not gotten them together as yet. If I had had this paper before me at the time of presenting my arguments to the city council as to rates, I feel certain I could have gotten them over to my way of thinking without any trouble; but I had to depend entirely upon original formulae.

There is one other thought suggested by this paper and from the preceding remarks. Assuming the hydrant rentals based upon the figures presented in this paper are fair to the city and to the water company furnishing the water, why should they not be as fair to the city as the recipient of the service and also the giver? In other words where the city owns its own water plant why should not a charge be made to the city as a corporation for the hydrants, such charges to be collected from the general taxes and credited to the operations of the waterworks?

This is the method pursued in a few communities but very few. But it is certainly a fair one. For instance a dwelling assessed for $10,000, may pay as much for the water used in it as a factory assessed for $100,000. Where no hydrant rentals are charged against the city the $10,000 building is then paying as much for fire protection as is the $100,000 factory. Whereas if the hydrant rentals were collected from the general tax levy the factory would bear a more equitable share of this burden. Hydrant service is no part of the service of furnishing water for domestic and manufacturing purposes and the latter service should not pay for the former. If this principle was more generally recognized, water rates would be lower in most communities, although tax rates might be higher; but the residents would be paying for the service received upon a fair basis.

Mr. Salmon: In my experience in connection with interior water service and sprinkler head risks, there is one point that I would like

to have some information on, namely, as to the extra risk and the extra cost of such risk. I have in mind a case in Illinois in which I was interested, where a factory burned down and the main leading to it was broken by the dropping of the floors above, which entirely disabled the fire pressure all over that neighborhood. In some such cases they have insisted on taking off a 6-inch pipe leading out into the interior of the factory, going over the several floors, and crossing over with reduced pipes, and if some heavy construction falls from above and goes down through, unless it is an entirely fire proof building, it will cut off your ability to stop the fire from outside. Now I believe that a charge should be made for that kind of a risk. I believe that a water company is entitled to something for that risk, because it certainly has the risk and should not have to undertake it for nothing; otherwise you are only encouraging people to put those pipes in all kinds of buildings, frame buildings and everything of that kind and because of the saving in insurance they are willing to pay for them.

We in Wisconsin are now getting the benefit from the Railroad Commission that the fire hydrant serivce is considered as a public municipal charge in connection with water for the school houses and hospitals, street flushing, and street sprinkling. The Wisconsin Commission are charging the city for whatever water they use no matter for what purpose; and in doing so they give credit for the reduction by a reduction in the private rate to the people, which is a very satisfactory method of procedure. The city should pay their proportion of this expense, not only the proportion of the expense due from the enlarged fire protection, expenditure for pipes, power and water supply, but also for the other water which they receive. I hope that this hydrant matter will be continued a little further on and investigation made of the proper rate for other things for which the municipalities themselves are directly interested and covering other uses of water by them. This would solve a question that has given rise to much dispute with private companies, and it would also assist them in forming better rates for the people themselves. But the fact of the case is that the city governments are so interested in getting fire hydrant rentals down that they do not seem to care whether the people have to pay more or not; we all know that most of our troubles come from the people thinking they have to pay too much for domestic water supply. I wish you all could move up into Wisconsin and get some of the benefits we are receiving up there.

Mr. Reimer: I want to express my personal appreciation of this paper, which has come at a most opportune time, and is bound to take a most conspicuous place in our records. It is a subject with which we have been struggling in our city and with regard to which we are trying to arrive at some definite conclusions. Our work is in the direction of getting a proper charge against the other departments, including, of course, the charge against the fire department for fire protection service.

There is one question I wish to ask Mr. Metcalf, and that is whether, when talking with Mr. Booth, engineer of the Board of Fire Underwriters, he was shown certain plats that the underwriters' engineers had made up showing hydrant spacings based on length and also on area protected. I have talked with Mr. Booth about this very matter and along the same general lines and am wondering whether those plats could not be included in Mr. Metcalf's paper, to the advantage of us all, if the Board of Fire Underwriters would permit it. The data given by these plats are of considerable value. Of course the authors of the paper might not care to incorporate that class of material, but the plats exhibit certain facts that I had not been able to procure previously except through the most difficult work, involving writing to a large number of cities throughout the country.

Speaking of the question of hydrant rentals and the attitude of the insurance companies, it seems to me that there is one point to be said in favor of the insurance companies or underwriters, though I do not know but that the hammers that have been working this morning were justly used. I refer to the fact that many of the various insurance companies with whose representatives I have talked, intimated that it is practically impossible to make reductions to a large extent throughout this country, owing to the number of exceedingly heavy losses suffered by them during the past ten or twelve years. All of us are familiar with these large losses that thave come within recent years, wiping out hundreds of millions of dollars valuation, a a very heavy proportion of which loss has fallen on the insurance companies. That is the excuse or reason advanced by them to me, though whether it is based fully on facts, and facts only, or whether the companies can really make reductions and at the same time carry the burden imposed by the recent conflagrations, are questions that I am not prepared to answer.

Another speaker raised the question regarding fire line charges and I wish to say just a word on that subject. In our case we have endeavored to meet this question of charge for private fire service and

have done it in this way: We make a charge of 25 cents per $1000 of assessed taxable value of buildings and contents. We do not claim that this is the best plan that can be adopted, but it is at least a start in the direction of finding a proper method of charging for the risk assumed by the various municipalities or private water companies for this class of service.

Mr. Metcalf: May I interrupt the discussion long enough to answer the question asked by the previous speaker? I had hoped that Mr. Booth would be present at this convention. Unfortunately he was not able to come. Mr. George W. Booth, the chief engineer of the National Board of Fire Underwriters, very kindly gave us copies of the curves referred to by Mr. Reimer, and I would suggest to the secretary of this Association that I think it would be to the interest of the Association if he will invite Mr. Booth to present that material to us at the next convention. I feel sure that Mr. Booth would do that; and it is but fair to say of his organization that the studies which it has been making are of intensely practical value, as they have addressed themselves to the problem essentially from an engineering point of view. They have not had to deal with the rate question. That has been taken up by other branches of the insurance service. They have dealt with the matter solely from an engineering point of view. There is every reason therefore why we should be able to get together with them with the utmost friendliness and cordiality.

Secretary: The three diagrams referred to by Messrs. Reimer and Metcalf, were very kindly supplied by Mr. George W. Booth, chief engineer of the National Board of Fire Underwriters, and are given herewith.

Diagram No. 1 shows the Linear Hydrant Spacing for the Congested Value District of a number of cities, spaced according to population.

Diagram No. 2 shows the Gate Valve spacing for the Congested Value District and the Residence Districts of the same cities.

Diagram No. 3 shows the area served by each Fire Hydrant in the Congested Value districts and the Residence Districts of the same cities.

Mr. Blauvelt: Referring to that section of paper which mentions the claims of makers of special apparatus for extinguishing a fire, who argue in favor of moderate water charges on the ground that less water is so used than for fires requiring the attention of the public fire department.

It would seem fair to call attention to the fact that while such argument on the part of private interests has some merit in some cases, the real or controlling consideration is not at all whether the charge is or is not sufficient to properly pay the water works for the service.

The only necessity and the prime consideration for using public water works as a supply to special private apparatus or sprinkler systems is that the public pressure service can usually be obtained cheaper than to put in complete private double sources of supply, i.e., use public water as one source.

Every standard sprinkler equipment must have two sources of supply, and therefore each equipment owner has to provide one source as a private source of supply except in those very rare cases where the public streets carry two sets of public service mains.

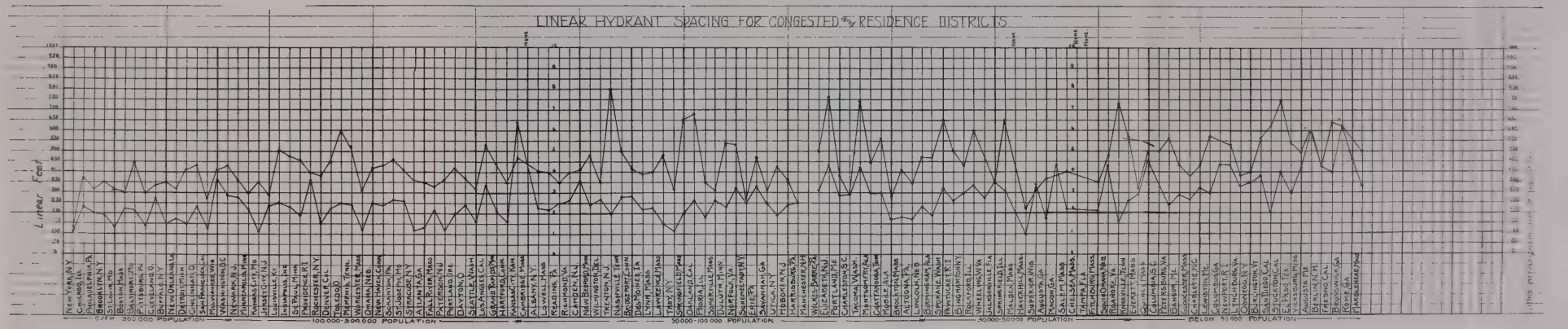
For isolated risks and for cities where the water pressure is too low to furnish a satisfactory supply on the top floor, the automatic systems have to be and are supplied by private double source supply and are granted as low rates of insurance as apply to those equipments using public water supply.

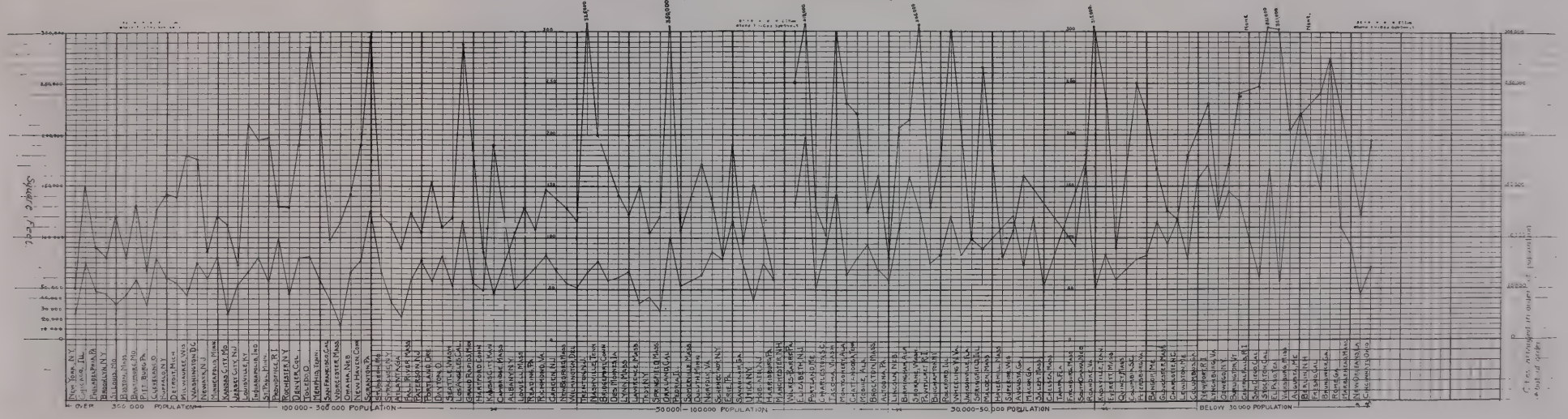
From this it is obvious and also a fact that there is no insurmountable necessity for any private equipment using public water supply in any case except as the public water supply may be of advantage in that it is cheaper.

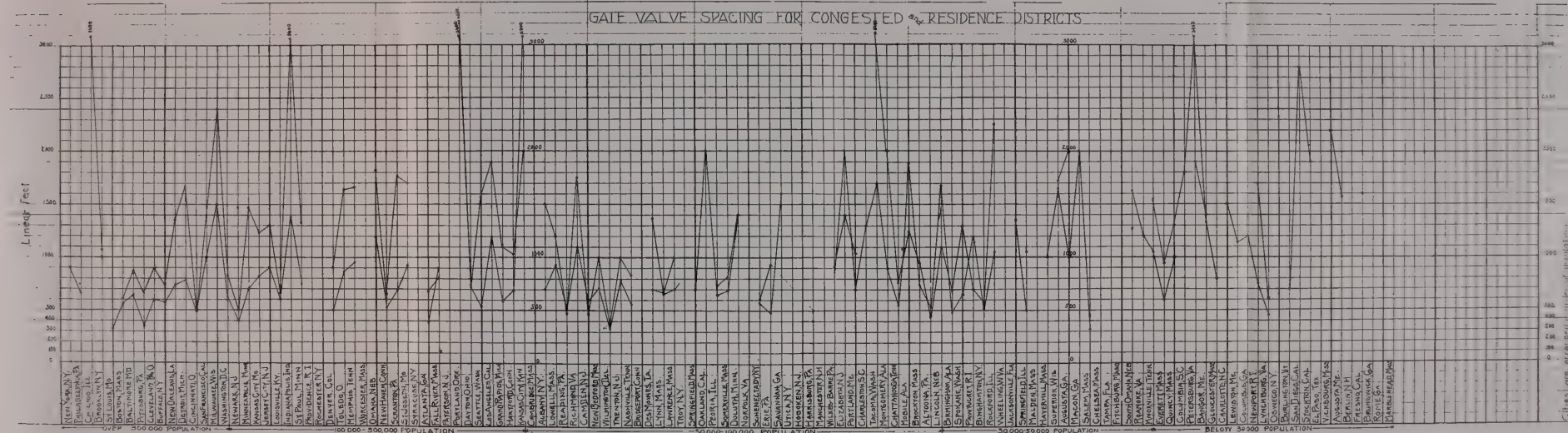
The measure of the situation in the minds of the property owners is therefore one of comparison between the cost of putting in one private supply and city water, or, two private supplies without city water.

City water is usually cheaper as to first cost and therefore is usually elected by property owners particularly where it can be had without any rental charge, or where the rental charge would not exceed the interest, depreciation and maintenance charges of an additional private supply to obviate the use of city water, such interest, depreciation and maintenance charges running as low as $100 per year in some cases and as high as $1000 in other cases, with probably an average somewhere around $200 per year.

It would be nonsense to suppose that any special insurance interests have the power of choosing whether private water supplies or public water supplies be used, the competition among insurance interests being such as to compel and cause the insurance to side with the property owner toward the cheapest available sources of supply capable of doing the requisite extinguishing work.


LINEAR HYDRANT SPACING FOR CONGESTED % RESIDENCE DISTRICTS
Linear Feet
None
None
None


AREA SERVED BY EACH HYDRANT CONGESTED and RESIDENCE DISTRICTS
100 000 - 300 000 POPULATION
30 000 - 100 000 POPULATION
30 000 - 50 000 POPULATION
BELOW 30 000 POPULATION


GATE VALVE SPACING FOR CONGESTED & RESIDENCE DISTRICTS
Lineal Feet
Cities are arranged in order of population
NEW YORK, N.Y.
PHILADELPHIA, PA.
CHICAGO, ILL.
BROOKLYN, N.Y.
ST. LOUIS, MO.
BOSTON, MASS.
BALTIMORE, MD.
PITTSBURG, PA.
CLEVELAND, O.
BUFFALO, N.Y.
NEW ORLEANS, LA.
DETROIT, MICH.
CINCINNATI, O.
SAN FRANCISCO, CAL.
MILWAUKEE, WIS.
WASHINGTON, D.C.
NEWARK, N.J.
MINNEAPOLIS, MINN.
KANSAS CITY, MO.
JERSEY CITY, N.J.
LOUISVILLE, KY.
INDIANAPOLIS, IND.
ST. PAUL, MINN.
PROVIDENCE, R.I.
ROCHESTER, N.Y.
DENVER, COL.
TOLEDO, O.
MEMPHIS, TENN.
WORCESTER, MASS.
OMAHA, NEB.
NEW HAVEN, CONN.
SCRANTON, PA.
LOUISVILLE, KY.
SYRACUSE, N.Y.
ATLANTA, GA.
FALL RIVER, MASS.
PATERSON, N.J.
PORTLAND, ORE.
DAYTON, OHIO
SEATTLE, WASH.
LOS ANGELES, CAL.
GRAND RAPIDS, MICH.
HARTFORD, CONN.
WASHINGTON, D.C.
CAMBRIDGE, MASS.
LOWELL, MASS.
READING, PA.
CAMDEN, N.J.
RICHMOND, VA.
NEW BEDFORD, MASS.
WILMINGTON, DEL.
TRENTON, N.J.
NASHVILLE, TENN.
BROCKTON, MASS.
DES MOINES, IA.
LYNN, MASS.
HOBOKEN, N.J.
TROY, N.Y.
SPRINGFIELD, MASS.
OAKLAND, CAL.
PEORIA, ILL.
SOMERVILLE, MASS.
DULUTH, MINN.
NORFOLK, VA.
SCHENECTADY, N.Y.
ERIE, PA.
SAVANNAH, GA.
UTICA, N.Y.
HOBOKEN, N.J.
HARRISBURG, PA.
MANCHESTER, N.H.
WILKES-BARRE, PA.
EASTABETH, N.J.
PORTLAND, ME.
CHARLESTON, S.C.
TACOMA, WASH.
MONTGOMERY, ALA.
CHATTANOOGA, TENN.
MOBILE, ALA.
BERKELEY, CAL.
LINCOLN, NEB.
BIRMINGHAM, ALA.
SPOKANE, WASH.
PAWTUCKET, R.I.
BINGHAMTON, N.Y.
ROCKFORD, ILL.
WHEELING, W.VA.
JACKSONVILLE, FLA.
SPRINGFIELD, ILL.
MALDEN, MASS.
SAVANNAH, GA.
AUGUSTA, GA.
MACON, GA.
SALEM, MASS.
CHELSEA, MASS.
TAMPA, FLA.
FITCHBURG, MASS.
SIOUX CITY, IOWA
ALTOONA, PA.
MANCHESTER, N.H.
GALVESTON, TEX.
QUINCY, MASS.
COLUMBIA, S.C.
PETERSBURG, VA.
BANGOR, ME.
GLOUCESTER, MASS.
CHARLOTTE, N.C.
LEWISTON, ME.
COLUMBUS, GA.
CHESTER, PA.
LYNCHBURG, VA.
OGDEN, UT.
BURLINGTON, VT.
SAN DIEGO, CAL.
STOCKTON, CAL.
EL PASO, TEX.
VICKSBURG, MISS.
AUGUSTA, ME.
PERTH, N.J.
PERTH, N.J.
BRUNSWICK, GA.
ROME, GA.
MARBLEHEAD, MASS.
1000
2000
3000
1500
2500
500
100 000 - 500,000 POPULATION
50,000-100,000 POPULATION
30,000-50,000 POPULATION
BELOW 30,000 POPULATION

MR. GEORGE W. BOOTH[1]. (By letter.) I was much interested in reading the paper on Fire Hydrant Service presented at the recent convention of your Association, and the discussion thereon. While apparently foreign to the subject matter of the paper, we feel that the nature of parts of the discussion calls for a statement as to the functions of the Board with which the writer is connected.

A quotation from the constitution of the National Board of Fire Underwriters and a statement as to the work it is now carrying on, will doubtless serve to acquaint the members of your Association with the nature of its activities and make clear the fact that the work carried on by the Board is wholly divorced from the question of rates of premium of fire insurance, and that it is almost entirely of an educational engineering and public service character.

The purposes of the Board as stated in its constitution are as follows:

First—To promote harmony, correct practices, and the principles of sound underwriting. To devise and give effect to measures for the protection of the common interests, and the promotion of such laws and regulations as will secure stability and solidity to capital employed in the business of fire insurance, and protect it against oppressive, unjust and discriminative legislation.

Second—To repress incendiarism and arson by combining in suitable measures for the apprehension, conviction and punishment of criminals guilty of that crime.

Third—To gather such statistics and establish such classification of hazards as may be for the interest of members.

Fourth—To secure the adoption of uniform and correct policy forms and clauses and to endeavor to agree upon such rules and regulations in reference to the adjustment of losses as may be desirable and in the interest of all concerned.

Fifth—To influence the introduction of improved and safe methods of building construction, encourage the adoption of fire protective measures, secure efficient organization and equipment of fire departments, with adequate and improved water systems, and establish rules designed to regulate all hazards constituting a menace to the business.

Perhaps the most active committees are those on lighting, heating and patents, on statistics and origin of fires, on construction of buildings and on fire prevention. In pursuance of its activities the board issues yearly large numbers of pamphlets of rules for the construction and installation of almost every conceivable fire protective or hazardous device, and through the underwriters laboratories in Chicago, which are under the direction of the National Board, makes tests of

[1] Chief Engineer, The National Board of Fire Underwriters.

such devices; the board has prepared a model building code, of which thousands of copies have been distributed, and is constantly advising and coöperating with city officials regarding the best practice in protection and construction; it has prepared model laws and ordinances on various subjects having to do with fire prevention; and through its committee on fire prevention has issued the reports on conditions affecting the fire hazard in the various cities of the country. The relations of the engineers of this committee with the members of your association and with water works managers in general have been, almost without exception, of the most cordial and friendly nature, and we feel that mutual gain cannot fail to result from such coöperation.

As previously stated, the National Board is forbidden by its constitution to deal with questions pertaining to rates, which devolve upon local boards having jurisdiction in their respective cities, states or larger subdivisions, and these local boards are subject only to such instructions as company members may give. The reports of the committee on Fire Prevention are sent to these local boards as a matter of course, just as they are sent to the officials and press of a city, but are intended only for their information and guidance, and the boards are in no sense bound by our findings or to urge the adoption of the recommendations.

As brought out in the remarks of Mr. Metcalf, these reports are prepared by engineers who have had education and training in the lines along which they work, and who address themselves to the problem essentially from an engineering point of view, without consideration of the rate question. It is hoped that in course of time the influence of these reports will be felt in the view point taken by the various insurance organizations, and that greater uniformity will result, as as well as closer harmony with the aims and ends of the American Water Works and kindred associations.

I would like to call your attention to the resolution adopted in 1905 at a joint meeting between committees of your association and of the National Fire Protection Association, as follows:

> That it is the sense of this conference that an apparatus embodying an indicating check-valve which shall not afford an initial resistance greater than about six per cent of the available pressure, with a metered by-pass, will prove acceptable on fire risks to both committees represented in this conference.

This resolution was ratified by the full convention of your association and later by the full convention of the National Fire Protection Association, in May 1905. To the best of my knowledge, no action

has since been taken by the National Fire Protection Association in this matter.

I would also refer to the chapter on Meters on Fire Services, by Mr. E. V. French, in the 1909 edition of the Crosby-Fiske Hand Book of Fire Protection, in which after noting the reasons why the ordinary types of meters are objectionable, and noting also the methods adopted in various instances to prevent improper use of water from fire services, Mr. French goes on to say that where some constant watch for a fire service is considered absolutely necessary, some form of detector on each fire service may be used, and describes the principle of the detector meter.

PRESIDENT ALVORD: The apportionment of fire protection payment on the basis of the hydrant is certainly a wrong method. I have come to the conclusion that it is an inequitable method. It certainly leads in the case of private companies to fire losses, by reason of the fact that very often cities do not wish to order extension of lines having hydrants upon them, thereby increasing the total amount paid for hydrant rentals, especially where such extensions occur in outlying residence districts. This is a very common occurrence.

Now there is something to be said for the city's lack of desire to order these hydrants. The price seems to them large, and the property protected is small, and such hydrants if you are going to go on a basis of so much per hydrant are not worth anything like what a hydrant would be worth in a congested central district of a city.

Therefore, it has occurred to me in adjusting these matters for new franchises to suggest what I might call a graduated hydrant rental, based on the value of the hydrant as fire protection, with regard also to the property which that particular hydrant would protect; taking the hydrant rental as a whole and reapportioning it among the hydrants. The thought has occurred to me in this connection of adjusting it on some such basis as the size of the pipe, or main from which it feeds. This is of course only a very rough approximation of the value of the hydrant; but it might have the advantage of simplicity in some cases; thus, for instance, a hydrant with large mains being at a price above the average and a hydrant on small outlying mains below the average. This I think might be an aid to cities where there is a disinclination to extend hydrant service and to increase the total hydrant rental.

Another basis for a graduated hydrant rental might be the population per acre.

A number of methods might suggest themselves readily to anybody who would study this subject whereby prices for hydrant rental might vary in proportion to the value of the hydrant for fire extinguishment.

This is a matter to which I have only brought casual study. It is a study in which I hope to receive a good deal of help from the papers that have been presented. I merely offer these suggestions for consideration in connection with your study of this subject.

MR. WORRELL: At Meridian, Miss., there is an annual assessment and tax levied to cover water for municipal use. It is a municipal plant, but operated by a commission. The price per hydrant is not stated at all, and the tax when collected by the city clerk or tax collector is paid over to the water commissioner. We get about $10,000 a year for hydrant rentals and the water for city uses; and when in the judgment of the board of council and aldermen they need another fire plug, a requisition is made on the commission, and the hydrant is placed.

In thinking about that in connection with what Mr. Alvord has just stated, it strikes me that for a private company it would be a very good scheme to make a lump sum based on the dimension. Of course there would be held in view the revenue to be derived from it. Having been connected with a private company a long time myself, that strikes me as a good way to settle what might otherwise be a troublesome matter.

MR. WILLIAMS: Mr. President, I shall not undertake to discuss this exhaustive paper, but rather to express a few thoughts suggested by the discussion.

I agree with Mr. Alvord that basing the payment for fire protection upon the number of hydrants is wrong. There is no necessary relation between the value of fire protection and the number of hydrants. But an effort to grade the value of the individual hydrants would probably be rather complicated.

In the determination of the charge which should be made for public service, it seems to me that the first step is to ascertain what proportion of the total revenue which the plant should have to properly maintain itself, is ascribable to that service; that is, what per cent should the Municipality pay for public service? Whether it should be 20, 30, 40 per cent, or something greater, will depend upon the conditions of service, the kind of city, and what is accomplished, in the

way of fire protection. If the water works are operated on the direct pressure system, enabling the city to dispense with fire engines entirely, as is often the case in small cities, that would be a factor requiring a greater percentage than if fire engines must be used.

It seems to me that the distribution of the total sum for fire protection will automatically adjust itself by reason of the fact that all property is assessed, or is supposed to be assessed in proportion to its value, and a general tax levied by the city for such purposes, would necessarily be distributed in proportion to this value. Hence there appears to be but one problem involved, namely, the determination of the sum which should come from public sources. I may be wrong about it, but I fail to see how any fairer way to assess benefits for fire protection can be found than in proportion to the value of the property.

There is generally insufficient consideration given to the cost and maintenance of fire hydrants. Public service is a large factor in the total service rendered by any water works plant, and such service should be furnished at the expense of the general public and not by the private user of water. This is true whether the plant is a municipal plant or otherwise.

In cases where there has been occasion to go into the proportion which should be carried by the city as a whole, I have found it to vary from 20 to 45 per cent of the total revenue.

Where capacities of the different parts of the plant are dependent almost wholly on private consumption, the proper per cent may fall considerably below twenty, though this is probably true only of very large cities.

H. F. DUNHAM: (By letter.) The writer wishes to express his thanks to the authors and his appreciation of their paper.

The first reading of the second statement as published in the abstract namely,

> 2. These hydrant rentals rarely bear any relation to the cost or the value of the service rendered.

gave an impression unlike that derived from experience and further consideration seems to strengthen the impression. Pumping station, pumps, distribution systems, etc., are property and naturally subject to common property relations. If it be known that a business block or a bridge cost $80,000 a reasonable though not an accurate idea of the structure can be formed. If one house rents for $250 per year and

another house for $2500, it is to be expected and in most cases it will be found that the sums paid do bear a consistent relation to the cost of the houses and to value received by the tenants.

Now as a matter of fact is it different in the case of hydrant rentals? Risks are greater and costs are higher in certain parts of the country but the writer's limited experience would lead to the conclusion that where hydrant rentals are very low there exist feeble works, small mains, few simultaneous fire streams and poor service. Conversely, where hydrant rentals are high, there are strong works, large mains, many fire streams and good service. There are doubtless exceptions, due sometimes to endowments or charity or unbalanced rates or other causes but instead of placing an important industry in a class by itself under unique conditions it might be well to examine anew the replies submitted or to seek to discover whether the method adopted is quite satisfactory in reaching a broad generalization.

Nearly all franchises in the middle west and further west contain sections providing for the location of hydrants by the city in any desired number per mile of main wherever a main has been laid with a specified number (usually ten) of "paying" hydrants to the mile. The city in such cases pays the cost of providing the extra hydrants and a nominal sum per year for maintenance but pays no rental. On account of this provision expressed in the "additional hydrant" clause as it is called, the amount of hydrant rental per mile of main in the distribution system is generally first thought of and mentioned by engineers and investors. Results obtained by dividing the aggregate sum paid in rentals by the total number of hydrants would not give information so valuable as that obtained by using as a divisor the number of miles of mains in the distribution system.

In reaching conclusions from averages it is important that the things averaged should be properly related to each other. Especially is this true if the averages are to form an expression, the expression a curve, and the curve a guide forfuture workers. For illustration, consider curves that limit or show the relation of the quantity of water used for fire protection to the quantity used for domestic purposes.

There are waterworks plants under an every-day pressure of 120 pounds to the square inch. When a fire occurs the pressure falls off to 100 pounds or possibly to 85 pounds and the amount of water supplied for domestic use is materially reduced while the fire rages.

There are water works plants under an every-day pressure of 40 pounds to the square inch. When a fire occurs the pressure goes up

to 85 pounds or 100 pounds or perhaps 120 pounds and before a fire hydrant is opened the quantity of water delivered through domestic and public connections and leaks has been nearly doubled or more than doubled.

Can a curve derived from these widely different conditions be of great value? It is true that plus and minus quantities can be averaged with algebraic accuracy but it may be difficult to discover what the result means in terms of human knowledge which is mostly human experience. The average height of a group of men can be determined if the heights of all are known, but if the heights of several and the girths of the others are given the task is more difficult. Men are so different. Water works too, are different. These differences are real difficulties and find expression in the various conclusions respecting what is required for good fire protection.

In a case of record the management of the plant is good and the daily consumption is small for the population. If we let a equal the quantity of water for fire protection as fixed by the district underwriters and based upon the consumption, then $5a$ will be the Hazen requirement based upon population and about $3a$ + the demand of Kuichling, as there are no natural bodies of water for outside apparatus to use and if there were they might be too far from a large fire.

In the writer's opinion all of these estimates are too low for that city. Many cities offer worse conditions and risks.

In construction the cost of furnishing 20 per cent more water than the most generous formula quoted above demands, would not be excessive, especially in medium sized and smaller cities, while the advantages in an emergency would be enormous. In this country the emergency is apt to occur.

Nothing in this comment should detract in any way from the great value of the paper under consideration. The paper itself contains words of caution against the unwise use of curves and conclusions. Those excellent words are merely supplemented by these few sentences.

EMERGENCY INTAKES

By Dr. William P. Mason

When an improved water is substituted for a former polluted supply it is a common and an unfortunate practice to allow the old connections to remain in place so that, in the event of an "emergency," valves may be opened and water from the abandoned intake be admitted to the city mains. Insurance rates depend upon ability to secure water for fire protection and insurance men are not especially particular as to the quality of water furnished for such a purpose. While we recognize the force of the argument which demands protection against fire, we cannot remain totally deaf to the question, "How much does such protection cost?" an inquiry which in some cases almost takes the form, "Which would a man prefer, loss of his house by fire or death from typhoid fever?"

"Fire protection" has been very destructive of human life at times and we again inquire, is it wise to pay that kind of price for it? Ordinary sewage, being largely water, will readily put out a fire, but it is doubtful if the most stalwart advocates of an "emergency" system would approve of admitting straight sewage to the street mains, even in the event of great danger of conflagration. The people at large would oppose such use of sewage, but with polluted water they are willing to "take chances" in times of stress, being ignorant of the fact that they are dealing with "certainties" not "chances" when they open their "emergency" gates. Let a few instances speak for themselves.

At Newark, N. J., in February, 1899, because of water shortage, the polluted Passaic river was drawn upon for the city's supply. As a result there developed 395 typhoid cases and 50 deaths. It is true that public notice was given of the proposed use of Passaic water, but the bulk of the people are very careless about sanitary matters and ordinarily pay small attention to such warnings.

At Lowell, Mass., in 1903, during the progress of a large fire, grossly polluted water was pumped into the city mains by reason of failure of certain check valves to seat themselves properly. An "emergency" arrangement then existed whereby connection could be established between private fire lines and the city system. This "arrangement" resulted in 231 typhoid cases and 10 deaths.

At Butler, Pa., on October 20, 1903, the filtered water supply became temporarily unavailable and polluted water was admitted to the mains from a former river intake. A serious epidemic of typhoid fever followed, resulting in 1270 cases and 56 deaths.

At Ottawa, Can., on January 4, 1911, "the emergency valve at Pier No. 1 was operated for some five hours and the pumps worked at a high rate of speed to pour water upon a burning storehouse." Two weeks later a typhoid epidemic broke out with a record of many cases and deaths.

Still more recently a western city with which the writer had to do developed a serious typhoid epidemic which was traced, at least in part, to leakage of polluted water around a closed gate of the old emergency intake. There followed over 800 cases of typhoid and a rather high death rate.

Do these "emergency arrangements" pay? Is it good economy to put out a fire at the cost of much suffering and many human lives? Is it not wiser and cheaper and more humane to derive our emergency supplies from sources that are not greatly inferior to those that furnish the water regularly delivered to the people? Even an indifferent water improved by a sufficiently long storage would be distinctly better than the "fire reserve" now too commonly employed.

DISCUSSION

Mr. Knowles: The question of emergency intakes is a very important one to the water works engineer and to the public. I thoroughly agree with Dr. Mason in the general conclusion he has reached, as to the danger of permitting any connection between a polluted water and the distributing system in works where the water supplied has been rendered satisfactory from a sanitary standpoint, either by filtration or by some other means.

During the preparation of plans for the Pittsburgh Filtration Works, this same problem arose and a few words regarding the way in which it was solved there may be of interest.

Before the construction of the filters, the water supply of Pittsburgh was received by gravity from cribs in the bed of the Allegheny River into the five suction wells of Brilliant Pumping Station. From these wells, the water was pumped to two distributing reservoirs of the city, without undergoing any purification.

Now the water is taken directly from the river through an intake chamber and is raised, by centrifugal pumps at the new Ross Pump-

ing Station, to large sedimentation basins. From these, the water flows by gravity through the filters and then through a large conduit to the filtered water reservoir. This reservoir, situated on the north bank of the Allegheny River, is directly across from Brilliant Pumping Station. From this reservoir the water flows through two 72-inch steel mains, laid below the bed of the river, into an equalizing chamber at Brilliant, and finally to the pump chambers.

Prior to designing the improvements made necessary at Brilliant by the change in supply, the question arose as to whether there should be provision made to take water directly from the river in case of an emergency, and should the filtered water be simply turned into the existing wells, which might not be absolutely tight against the inflow of unfiltered water (at some stages of the river). Both of these considerations were decided in the negative; although there was much adverse discussion that pumps would synchronize in movements and thus cause damage and that it was unwise to not allow for an emergency supply.

As finally constructed, the filtered water passes from the equalizing chamber to a steel trunk line and thence directly through cast iron pipes to the suction chambers of the various pumps. The steel trunk line has two manholes and each of the cast iron suction lines has one special casting with a blank flange; but these openings were necessary to afford opportunity for inspection of and repairs to the lines and are not regarded as possible emergency inlets. All of the river connection lines from the wet wells have been cut off, except one which was retained to permit the discharge of jet condenser water.

Throughout the entire plant great care has been taken to prevent the contamination of the filtered water. There is no way in which a filter can be by-passed (or unfiltered water sent into filtered water pipes) by the opening of a valve; so we believe that every known precaution has been employed to protect the quality of the water from being endangered by the opening of the wrong valve, be such act intentional or simply due to carelessness.

The change from a polluted water to one satisfactory from a sanitary standpoint, is generally followed by the people gradually ceasing to follow the precautions which are so often adopted by those who understand the danger of using polluted water. The municipality or the private water company, as the case may be, by constructing a filter plant or securing by other means a better quality of water, practically assumes a responsibility to the consumers which cannot be over-estimated. The consumers, by such action on the part of the

company or municipality are given to understand that the new supply is free from disease germs; that the water may be used without danger to health. There is a moral responsibility resting upon those in charge of the water works to maintain the purity of the supply. There may arise conditions which could not reasonably have been guarded against and which make it absolutely necessary to supply water which has not been subjected to the usual treatment, but even in such cases, there is no excuse for turning raw water into the mains without first treating it with a sterilizing agent for the time of such emergency service.

The fact, previously mentioned, that some companies and some municipalities show a lack of a proper appreciation of their duty as purveyors of water, to properly protect the health of the consumer; emphasizes the responsibility resting upon the designing engineer to avoid all pipe connections which could be used to so change the character of the water as to destroy that safeguard of public health, a safe and wholesome water supply.

Mr. Bass: This subject is one with which the speaker as engineer of a state board of health is much concerned. There are in his state (Minnesota) perhaps a dozen municipalities having dangerous "emergency" intakes. As yet no great disaster has resulted, but the danger is real and imminent, nevertheless.

It is true that we have the means for disinfecting water mains that were not available a few years ago. An emergency hypochlorite plant might be set up over every emergency intake and the danger greatly diminished, but as the author states, storage of pure water in sufficient quantities for the maximum fire demand is the true remedy.

The fire underwriters insist on fire protection and the life insurance companies, if they realized the seriousness of the abominable lack of sanitary precaution in many public water supplies, would also insist upon protection of life. It would seem that if the fire insurance companies can afford to employ a great corps of engineers to see that the water works are properly designed to contend with fire that an association of life insurance companies might easily afford to employ sanitary engineers to prevent loss of life from defective features of public works.

Mr. Ellsworth: I had occasion to look over a plant about a year ago where they had an emergency intake. They were drawing their regular supply from wells, with an emergency intake from the river.

the latter being sealed by the State Board of Health. I think it was a 12-inch suction pipe in the river. I inquired how long it would take to get permission from the state board of health to open it if they desired to, and I was told that there would be no trouble about that, they could cut off the stem of the valve and open it with a monkey wrench.

A STAND PIPE ACCIDENT

By H. C. Hodgkins

This is a view of an old stand-pipe and an old accident. A full account of the accident and the repairs can be found in *Engineering News* of August 18, 1894.

Although an old story it may be new to many of those present. To the water works manager who has a stand-pipe and is located in a cold climate, this accident is perhaps the most instructive of the whole list of accidents, in showing what takes place inside the stand-pipe during the cold winter months.

The water had frozen around the inside of the stand-pipe to a thickness of 4 feet and this ice extended in nearly uniform thickness from the bottom to the top of the stand-pipe. As the weather became warmer in the month of March, the ice thawed next to the iron, and a long portion of it became detached and floated in the water. When the water gauge indicated a full stand-pipe the ice could be seen projecting a considerable height above the top. A light southerly breeze would force this projecting ice against the side of the stand-pipe where it would naturally freeze, and the supposition is that it froze hard enough to hold it in that position when the water was drawn down in the stand-pipe.

At the time the accident happened the gauge indicated that the water was down 45 feet from the top, and at this level the weight of the hanging ice was so great that it fell, wedging itself into the lower portion of the stand-pipe with such force as to cause the vertical seam and horizontal seams of the sixth ring from the bottom to tear out along the rivet holes, and the sheets themselves to open outward like a pair of barn doors. The ice was forced through the opening with sufficient force to carry it about 250 feet, cutting down fences and telegraph poles. The stand-pipe remained filled with large chunks of ice up to the opening and a hollow cylinder extended about 25 feet above the break being somewhat thicker on the north side.

The accident clearly shows that ice in a stand-pipe forms around the inner circumference of practically uniform thickness. It also

A STAND PIPE ACCIDENT

emphasizes the necessity of watching the pressure and not allowing the height of water to vary to any considerable extent; especially as the longer days of spring approach when ice commences to thaw extra vigilance should be exercised. Whenever ice is seen projecting from the top there is great danger; and thereafter the pressure should be kept constant.

The height to which the ice projects above the top of the stand-pipe indicates the depth of ice which has become detached. For example, if ice is seen projecting above the top of a 100-foot high stand-pipe a distance of ten to twelve feet, it would indicate that solid ice 100 feet long was floating in the stand-pipe. The specific gravity of ice is about 0.92, and in the case of icebergs it is estimated that about one-eighth appears above the water.

When ice becomes detached and projects above the top, the danger is that the wind will force it against the side and relegation take place to sufficient extent to hold the ice when the water is drawn down.

In this case it is probable that a hollow cylinder of ice with walls 4 feet thick and 75 to 80 feet long and weighing 40 to 45 tons was floating in the stand-pipe and having been frozen to the top when the stand-pipe was full was held in that position as the water was drawn down. When the water was down 45 feet this suspended cylinder of ice, if 80 feet long, would have 45 feet of its length out of the water and 35 feet in the water. Its weight less the weight of water displaced by the submerged part would be about 22 tons. This weight of ice falling a distance of 7 to 10 feet before it struck the shoulder of the ice which had remained attached to the lower part of the stand-pipe, would break in, and wedge upon itself with terrific force. Of course, a much shorter cylinder of ice might become attached to the top and hold until the water had been drawn down much more than in this instance and then falling and breaking as it fell cause serious damage.

The fact that the ice was seen projecting above the stand-pipe two days before the accident a distance estimated at 4 to 8 feet, would indicate that a length of about 80 feet of ice was detached. This length would bring the point of the break at the separation between the floating ice and the ice that remained attached. The stand-pipe is 16 feet in diameter and 104 feet high.

The bursting out of the sixth ring from the bottom also damaged the fifth and seventh rings, so that in making the repairs the sheets of three rings for a full third of the circumference were removed and

replaced with new sheets. The stand-pipe is in use today with no evidence of this accident, and to the casual observer in as good condition as when built twenty-two years ago.

This stand-pipe is located at Cobourg, Ontario, on the north shore of Lake Ontario nearly opposite Rochester.

WOOD STAVE PIPE: SOME QUESTIONS ANSWERED

By T. Chalkley Hatton

From time to time during the past two or three years the writer has had numerous inquiries from parties interested in building and rebuilding water works, and who are seeking information concerning wood stave pipe. These letters and questions are growing in frequency; a week rarely passing without one or more. From the range of questions, there are two thoughts which have occurred to the writer; that wood stave pipe is becoming an interesting subject to the water works men, and that a good many persons seem to think the writer is an encyclopedia upon the subject. In answer to the last thought, he desires to inform his readers, that, while he has spent a good deal of time and energy during the past five or six years in studying the subject, and in making field experiments with wood stave pipe, he feels he is quite incapable of properly answering some of the inquiries referred to him; that, in answer to the first thought, it may prove interesting to the members of the American Water Works Association to reply to a few of the inquiries through the medium of the *Proceedings*.

The writer has been so often surprised at the character of the inquiries received from engineers and water works superintendents concerning wood stave pipe that he has come to believe that there are a great many men who do not avail themselves of the opportunity of reading much of the literature appertaining to their calling, but continue to solve the problems coming before them by the older methods without attempting to try the newer ones. Only a few months ago an engineer designed a gravity water supply for a small town in one of the southern states, and provided for a cast iron pipe main for several miles in length to be built through the mountains where the transportation cost, added to the cost of cast iron, made the cost of the layout greater than the municipality could stand, and the scheme was practically dropped, until a citizen in a town seventy miles distant, where a similar layout had been constructed with wood pipe at a great saving over cast iron, suggested using wood pipe. This suggestion looked good, the matter was reopened, the

plans and specifications redrawn, and the plant is about to be constructed within the limits of the funds available. This fact is mentioned to show that this engineer had either not heard of wood pipe, or, if he had, did not consider it worthy of much serious thought.

Wood pipe for conveying water to and through municipalities has been used "since the memory of man runneth not." The Romans used it for generations. Many miles of it were laid in the streets of London centuries ago, and last year some of these old pipes were removed from the streets, and were found in a good sound state of preservation. The early water works in the United States were built with wood pipe distribution mains; New York, and Philadelphia being well known examples. During the building of the New York subways some of these old wooden mains were encountered and removed. They were found perfectly sound. The pipes above referred to were made by boring pine logs and banding each end with a round wrought iron band. Making the two ends in the form of a tenon and chamber, and driving one into the other. This method of manufacture required the removal of the best part of the wood and yet the pipes have lasted for centuries. The writer removed several hundred feet of these pipes, from the streets of Wilmington some ten years ago, which had been in the ground since 1812, and not only was the wood as sound as the day it was buried, but the wrought iron bands were perfect. These facts are simply mentioned in answer to the oft-repeated question, "what is the durability of wood pipe."

It might well be asked "why, if wood pipe was so durable should cast iron and steel pipe have been substituted." The answer to that question is that the old method of making a wood pipe limited its inside diameter to the diameter of the log, and thus its place in the modern water installation was necessarily very much limited.

By the modern method of making wood pipe the diameter is unlimited. The largest wood pipe known to the writer being 9 feet 6 inches in diameter, made under the direction of Mr. John Birkinbine of Philadelphia. The quality of the materials entering into the construction of the modern wood pipe are far superior to that used in the ancient installations. The wood is cut out of the solid logs in the form of staves from 1 inch to 3 inches in thickness, and thus the best of the log is utilized, and the inspection of the staves is an easy matter both during construction and thereafter. The steel or iron bands can be properly inspected during manufacture, and

their placement properly inspected. So that there is no other character of pipe, whose quality can be better known, and observed than wood pipe.

This in itself is of great advantage to the constructing engineer or water works superintendent who so frequently has to remove a defective cast-iron pipe after completion of his work. A good comparative illustration of this trouble may be cited from the history of the "Water Supply of the El Paso and Southwestern Railway" as given by Mr. J. L. Campbell, M.Am.Soc.C.E., and printed in the *Transactions of the American Society of Civil Engineers*, vol. lxx, p. 182, in which Mr. Campbell states that in the 116 miles of wood stave pipe built into this line, and shipped from Elmira, N. Y., and Bay City, Mich. (about 3000 miles), from $\frac{1}{2}$ to 1 per cent was damaged by shipment, and that out of 100,000 pieces of wood pipe laid, less than six pieces had to be removed from the pipe line after the work was completed. While of the 18 miles of the 12-inch cast-iron pipe shipped from Chattanooga, Tenn., 6 per cent was damaged in transit, and 27 pieces were removed from the pipe line as having shown cracks under a pressure of 50 pounds. In both cases competent inspectors were maintained by Mr. Campbell at the place of manufacture to inspect and test the wood and cast-iron pipe, and no pipe was laid in the pipe line which had not been given a field test by the engineers in charge of the work.

The above facts, to which many more cases known to the writer might be added if space permitted, would reasonably answer the question, "what percentage of damage is there in transporting and handling wood pipe?"

There are two distinct forms of wood stave pipe in common use. One is termed "continuous" and the other "machine made." Both are built of the same character of wood, and the staves are of equal thickness for like pressures.

Thoses built into "continuous" pipe are made of uniform thickness throughout their lengths, with a bead on one longitudinal edge and with a saw kerf at each transverse edge into which a metal plate is inserted to make a water tight joint. The bead on the longitudinal edge serves to make a water tight joint by being squeezed into the face of its neighboring stave when the iron bands surrounding the pipe are cinched up. The staves are made in unequal lengths to enable joints to be broken in constructing the pipe. The staves are held together by round iron or steel bands of such diameters and spacing as will retain the pressures required. Each end of the

bands passing through a malleable iron shoe and having a thread to which a nut is fitted. Thus the staves can be brought together so close that no leakage can occur unless it oozes through the grain of the wood.

This form of wood pipe is built in the trench, and from 16 inches to any diameter required, but more commonly used for pipes over 24 inches in diameter. It has one special feature well worth noting, that if the pipe leaks at any joint in the longitudinal joints, these leaks can be easily stopped by cinching up the bands near the leaks or if some defect shows up in the pipe line a few years after building, sections can be easily removed and replaced, by substituting new staves, or new bands.

The staves built into "machine made" wood pipe have two beads upon one longitudinal edge and two corresponding grooves in the other longitudinal edge. The beads are a little larger than the grooves, and when cinched together the bead crushes into the groove, thus insuring its being totally filled and made water tight. At one end there is a tenon cut 4 inches long, where the staves are one-half the thickness of balance of the walls of the pipe. On the other end there is a chamber cut 4 inches deep. The tenon is smaller in diameter at the end than at the shoulder, and when driven into the chamber makes a water tight joint, even though the two shoulders are not in perfect contact.

The staves are cut radially to correspond with the diameter of the pipe, and are held together by a steel band, steel wire or copper clad wire. This band or wire is wound spirally upon the pipe by a machine. The high tension produced by the machine squeezes the beads into the grooves making a longitudinal joint that cannot leak so long as the elastic limit of the bands is not overcome.

Where steel is used for banding the pipe it is run through a bath of warm asphalt, which adheres to its surface, thus protecting it from any water which might ooze through the grains of the wood. After the pipe is wound, and the tenon and chamber cut, it is rolled in a bath of hot asphalt which adheres to the outside of the steel and wood protecting them from outside oxidizing agents. It is then rolled in a bed of sawdust. This sawdust enters into the asphalt and forms a protection for it in shipment and handling.

"Machine-made" wood pipes are made in lengths from 5 to 12 feet, and shipped to the work ready to be laid. They are laid by driving one piece into another until the two shoulders are in contact, or nearly so. No skilled labor is required; the inspector standing on top of

the trench can readily observe whether the pipe has been driven home by observing the two shoulders. This form of pipe is made for diameters from 3 inches to 36 inches. Either form can be laid around curves of from 90 to 200 feet radii, according to the diameter of the pipe.

One of the usual questions asked is "what pressure can wood stave pipe safely withstand?" The proper reply to this is that the tensile strength of the material composing the bands represents the pressure the pipe will stand. Wood pipes are made to withstand pressures up to 200 pounds to the square inch, so far as the writer knows. The more the pressure under which the pipes are subjected the more steel or wire required to band them together.

As the tensile strength and elastic limit of iron and steel are well known, it becomes a simple matter of computation to determine the gauge and spacing of the bands to make a wood pipe, which will withstand any pressure up to 200 pounds. Beyond this pressure it is likely the water would waste through the pores of the wood so that a higher pressure would not be economical or practicable.

The writer has experimented with wood pipe up to a direct pumping pressure of 300 pounds, without fracturing the pipe. This experiment was made to ascertain what a pipe built for pressures up to 100 pounds would do if it was subjected to a water hammer equal to three times the pressure. At 250 pounds the water oozed through the walls of the pipe. At 300 pounds it spurted in small streams at a few of the longitudinal joints, with a few leaks at the transverse joints. The pressure was suddenly removed to nothing and gradually brought up to 100 pounds, with the result that the leaks stopped. This showed that, while the steel bands had been stretched, the elastic limit had not been overcome, and the pipe would, under such conditions as frequently exist in a long pipe line, safely withstand a wide range of pressure suddenly applied.

Pressures from 100 to 150 pounds are common in machine made wood pipe, while continuous pipe of large diameter is successfully operating under pressures from 80 to 130 pounds. It is not the writer's purpose to advertise any particular manufacture of wood stave pipe, or the materials entering into their manufacture, and he therefore hesitates to name the many pipe lines both continuous and machine made with which he is somewhat familiar either as an observer or as designing and consulting engineer.

Assuming that wood stave pipe is laid where it will be constantly subjected to water pressure the life of such is entirely dependent

upon the life of the material with which it is banded. While the life is somewhat problematical there are well known illustrations where steel banded pipe has been in continuous operation for fifty years without apparent deterioration. While the writer has industriously made inquiries wherever such might be expected to give reliable information he has failed to learn of a single case where steel bands have given way on machine made pipe.

The engineer who designs a continuous wood stave pipe provides for at least a factor of safety of 3 in determining the size and spacing of his bands. The manufacture of machine made pipe provides for an equal factor of safety Now when steel or iron corrodes it does so by pitting, and thus it is reasonable to assume that two-thirds of the cross-section of the steel can oxidize before the band will fail under ordinary conditions. From the writer's observation sheet steel, such as composes the bands of machine made wood pipe, pits in irregular spots, and never on a straight line, thus the band may be two-thirds gone before the pipe will fail.

Where oxidizing agents are known to exist, such as in salt marshes, through salt water or sulphur deposits, the pipe should be banded together with copper clad steel wire. This copper clad wire is cheaper than solid copper wire. It has an elastic limit of about 50,000 pounds per square inch, a tensile strength of from 90,000 to 100,000 pounds and a coefficient of expansion less than two-thirds that of copper. Thus it becomes a product equal in strength with the steel and far better than copper. The writer knows of several cases where copper clad steel wire wound wood stave pipe has been successfully used where cast-iron and steel pipe were very unsuccessful.

The claim is made by wood pipe manufacturers that wood pipe has a greater carrying capacity than cast-iron pipe of equal diameter, and from a few well conducted experiments this claim seems reasonable. Marx, Wing and Hoskins conducted careful experiments to determine the coefficient of friction in wood pipes. See *Tran. Am. Soc. C. E.*, vol. 40. They found that coefficient "n" amounted to 0.009. Mr. Campbell on the El Paso and Southwestern Railway pipe line, heretofore referred to, found the value of "n" in 13,200 feet of 10-inch wood pipe to be 0.00866, and in 47,500 feet of 16-inch wood pipe to be 0.0092. See *Tran. Am. Soc. C. E.*, vol. 70, p. 182. Mr. Campbell had exceptional facilities for determining the true values of "n" which are rarely found in actual practice.

The value of "n" in new cast-iron pipe has been determined repeatedly, and found to be 0.012. From the results of these

experiments it appears quite true that a wood pipe has greater capacity than cast iron of like diameter. For instance a 12-inch wood pipe with a loss of head of 8.85 feet per 1000 will carry approximately 2025 gallons per minute, whereas a new 12-inch cast-iron pipe under the same loss of head will carry about 1810 gallons per minute. A 30-inch wood pipe under a loss of head of 2.05 feet per 1000 will carry about 11,600 gallons per minute, whereas a 30-inch cast-iron pipe under the same head will carry about 8810 gallons per minute. The longer the cast-iron pipe is used the less its carrying capacity, under frequent conditions. The capacity of wood pipe does not diminish with age, the inside perimeter becoming smoother from use.

So far as the writer's knowledge goes there have been very few well-conducted observations made of the leakage from wood pipe lines. From general observations made by the writer of lines in operation, no leaks of any significance have been apparent. Mr. Campbell, however, conducted careful observations on his lines, and states that, after two years, there was no material leakage in the 10 miles of 10-inch and 16-inch wood pipe line between the source of supply and the reservoir which pipe was working under a maximum pressure of 130 pounds. That in the 12.6 miles of 11-inch and 12-inch pipe lines below the reservoir, and subjected to a less pressure, the 11-inch line leaked 17,046 gallons per mile and the 12-inch about 3702 gallons per mile. Along the railway, when the maximum pressure was 130 pounds the 11-inch pipe leaked 120 gallons per mile and the $8\frac{1}{2}$-inch and $7\frac{1}{2}$-inch pipe leaked 268 gallons per mile. It occurs to the writer's mind that if there were 103.4 miles of wood pipe in this installation wherein the maximum leakage was 268 gallons per mile, and 8.6 miles wherein the leakage amounted to 17,046 gallons per mile, there must have been some defective joints or pipes in the latter section which needed looking after, that if 90 per cent of the whole line was practically water tight, the other 10 per cent could easily be made so.

However, from the result of the careful observations made by Mr. Campbell, it seems reasonable to assume that wood pipe, properly made and laid, can be made water tight under a pressure of at least 130 pounds.

This subject may be concluded by considering the difference in cost in installing wood stave and cast-iron pipe. This difference is made up of several items, as, for instance; the cost of the two characters of pipe delivered f.o.b. cars at nearest railway point.

Hauling pipe alongside of trench, width and depth of trench. Laying pipe, etc.

The difference in cost of furnishing and delivering the two characters of pipe at railway points is largely dependent upon the difference in diameters of the pipes to be used. The larger the diameter the greater the difference. The difference in weights per foot of pipe also increases in direct ratio to the increase in diameters. Therefore the cost of transporting wood pipe from railway to trench is from one-third, for wood pipe 8 inches in diameter, to one-sixth, for wood pipe 30 inches in diameter of the cost of transporting cast iron.

To overcome frost conditions the wood pipe need not be built as deep as cast-iron pipe, as wood is a good non-conductor, and can be laid closer to the surface of the ground without being damaged by frost. In laying wood pipe no bell holes are necessary, and this item of cost is eliminated, which, in rock excavation, becomes a very important item.

As there is no lead and hemp used in laying wood pipe these items of cost are eliminated, as is the cost of melting lead, transporting and furnishing fuel, and caulking joints.

While it is impossible to compile a table showing the difference of cost between furnishing and laying the two characters of pipe which will fit conditions existing generally, it can easily be determined at a glance that there is a difference in favor of wood pipe; that this difference depends upon the size of the pipe, and that it can easily be determined for each locality when freight and labor charges are known.

A few instances of known costs might be interesting. The 23 miles of 30-inch continuous wood stave pipe laid for supplying Lynchburg, Va., with water, under the direction of Mr. James H. Fuertes, M.Am.Soc.C.E., cost, for furnishing and laying pipe, exclusive of trenching and backfilling, from $1.82 to $2.10 per lineal foot, depending upon spacing of bands. This wood was shipped from the Pacific Coast at a freight rate approximately $300 per car.

The 42-inch continuous wood stave pipe laid as a supply main for the Atlantic City Water Works, under the direction of Mr. Kenneth Allen, M.Am.Soc.C.E., cost, exclusive of trenching and backfilling, $2.25 per lineal foot.

The 24-inch machine made pipe line laid under the direction of the writer for Carney's Point, N. J., cost, exclusive of trenching and backfilling, $1.32 per lineal foot.

Comparing the above costs with the cost of cast-iron pipe of equal diameter delivered f.o.b. cars at railway point, and the cost of lead and hemp for making joints, omitting transportation charges from railway to trench, la ing charges, extra excavation for bell holes, fuel for lead melting, caulking and handling cast-iron pipe.

The 42-inch cast-iron pipe would cost at $22.00 per ton $6.11.

The 30-inch cast-iron pipe would cost at $22.00 per ton $3.47.

The 24-inch cast-iron pipe would cost at $22.00 per ton $2.43.

The difference in cost of laying wood and cast-iron pipe, including trenching and backfilling, and under exactly the same conditions, is well set forth in Mr. Campbell's paper above referred to.

He states that the 384,300 feet of wood pipe from 11 to 3½ inches in diameter were laid at an average cost of $0.0472 per lineal foot, whereas the 101,200 feet of 12-inch cast-iron pipe, including lead and hemp were laid at an average cost of $0.2343 per lineal foot.

It is not the writer's purpose to recommend to his colleague, who may be interested in laying supply mains for water works, wood stave pipe under all conditions, but to suggest that, after knowing the conditions, he look into the advisability of using wood stave pipe, study its applicability to the existing conditions, including the comparative cost with cast-iron or steel pipe, keeping his mind open to recommending the installation which will best suit the conditions, and he will find many circumstances when he can save his clients' money and secure for him equal service.

Wood stave pipe has long been familiar to western engineers and water works superintendents. The great cost of transporting cast-iron pipe from the east was prohibitory and engineers were forced to use wood pipe. These, however, have proven so efficient after many years' trial that they are being used wherever conditions are proper. There are many contractors who make a specialty of installing continuous wood stave pipe, and there are several manufacturers of machine made wood pipe in the United States, prominent among whom may be mentioned the Washington Pipe and Foundry Company, on the Pacific Slope, the Eastern Manufacturing Company and A. Wyckoff & Son Company of Elmira, N. Y., Smith and Son of Bay City, Mich., and A. Wyckoff & Son Company of Alexandria, La. To those who are interested in securing detailed information upon wood pipe the writer would refer to the above-named manufacturers.

DISCUSSION

SECRETARY DIVEN: I presume the speaker has had about the longest and possibly most expensive experience with the old style wood pipe of any member of the association. When he first started in the waterworks business it was with a works having about 28 miles of wood pipe varying in size from 1-inch service pipes up to a 12-inch main supply pipe. In the later years of his connection with the works there was a great deal of trouble from leaks. But these leaks were almost always traceable to some original defect in the pipe. The manufacturers of the pipe were supposed to turn all the sap off the log before boring it; in some cases, for economical reasons I presume, they did not do this, and the decay would start in this sappy layer, and continue all through the pipe.

Leaks were also occasioned by loose knots, which should have caused the rejection of the log in the process of manufacture. The pipe after being banded was rolled in hot tar and then in sawdust, some two or three coats of tar and sawdust were put on. In transportation and handling this coating would be rubbed off, exposing the bands, in which case the bands were soon destroyed by rust, weakening the pipe, which depended on the banding for its strength.

Mr. Hatton spoke of its non-freezing qualities, and also as to its being a non-conductor. It had one other quality which he did not speak of. This spiral banded pipe was in 9-foot lengths, so that there was considerable length of band on each piece and chance for considerable expansion in case of freezing.

This paper was probably inspired more or less by a question asked last year as to what pipe was suitable to lay in salt marsh; and it strikes me that this wood stave pipe, or the old style wood pipe bored out of the solid log, with copper clad steel bands, might answer that purpose.

MR. WEHR: I should like to ask what have been the successes or failures in tapping wood pipe for small services?

MR. DIVEN: The process of tapping wood pipe is very simple. The corporation cock has a long tapering threaded end, with wood screw threads on the end to be inserted in the pipe. A hole is started in the pipe, deep enough to securely hold the cock, but not to let out any water. A piece of pipe having a stuffing box attached to one end is then screwed on the corporation cock, the shank of a long auger

bit passing through the stuffing box. The hole is then bored through the pipe and the corporation cock screwed in as far as possible, the auger withdrawn till it clears the cock and the cock shut off and the "tapping machine" removed. Such a tapping machine is not expensive, as compared with those used for tapping iron pipe under pressure.

Water is not shut off from the wood mains, they being tapped under pressure.

For large branches cast iron crosses and tees were used. These were standard cast iron fittings, but all spigot end and no bead. The ends of the wood pipe were reamed out, with a special hand tool, and the ends of the specials inserted; the end of the wood pipe was fitted with a heavy clamp to strengthen it, and wood wedges driven in to make a close joint with the iron.

Mr. Metcalf: May I ask Mr. Hatton how much experience he has had with copper-clad bands? I am very much interested in the suggestion which has been made, and would like to know whether any difficulty has been experienced in the cutting of the threads of those bands, or whether these bands are only used in the spiral wound.

Mr. Hatton: So far as I know that has only been used on the spirally wound pipe, and particularly around mining propositions where steel and cast-rion would not last, so they finally got hold of this copper-clad wire. It has been made only a short time to my knowledge, and it fills the bill very nicely, but I do not think they have used it on bands of continuous pipe because probably the cost would be so excessive that, except in special instances, it would not be practical. The cost of copper-clad wire is very nearly the cost of the copper itself. It fluctuates with the cost of copper. But still it fills that long felt want which engineers have experienced when they were building water pipes through a section where neither cast-iron nor steel pipe is long lived. Atlantic City has gone through an experience of that kind with which many of you are familiar. The question of copper bands was discussed many years ago when the officers of Atlantic City were talking about laying wood pipe in 1901. Instead of laying wood pipe at this time, 30-inch riveted steel pipe was laid. At the present time this pipe is so pitted from the electrolitic action due to the salt water that it has been found necessary to lay a 48-inch forcing main from Pleasantville to Atlantic City to take the place of the 30-inch steel main. It seems unfortunate, in the

light of what has occurred to this 30-inch steel pipe, that wood pipe with copper clad bands were not used in the first instance, as it would undoubtedly have proven cheaper in the end.

This new 48-inch forcing main has been laid as a continuous wood stave pipe banded with steel bands. The question of placing copper bands on this new wood pipe was considered but it was felt that the extra cost was such that it would be cheaper to replace a steel band two or three times rather than copper band once. I am not sure, however, that this would have proven the case if copper clad bands had been considered.

The present 48-inch continuous wood stave pipe is laid with its springing line about level with the surface of the salt water marsh, and the part above the surface has been covered over with the tussocks and earth from the surface of the marsh. The work has just been completed, and I thought it would be very interesting to hear a description of it by Mr. Van Gilder, chief engineer and superintendent. I believe this pipe is working under a direct pumping pressure of from 65 to 75 pounds, and I think it is about 35,000 feet long.

Mr. Van Gilder: It might be of some interest to the association to have a little description of that matter. If you want to put it in the form of a series of questions I shall be very glad to answer them if I can; or if you would like it in the form of a general description I would rather put it off until a subsequent meeting and prepare a few notes. What would be the pleasure of the meeting?

Mr. Hatton: I do not think any of you can realize what an interesting problem Mr. Van Gilder has had in Atlantic City, unless you could have seen it as I have seen it. I do feel that to the members of this association Mr. Van Gilder's description of what he has had to contend with and how he has solved the problem will very be interesting and probably valuable in the future to the members. I suggest that Mr. Van Gilder be asked to present this description later on in the session.

Mr. Yeager: How does this wood stave pipe work in a hilly country when you get above grade line, and have air in the pipe?

Mr. Hatton: You put in air valves, which are screwed in at every high point like any other tap. The air valves eliminate the air. That is what they are for. If you get the proper kind of an air valve they take the air out and leave the water there.

WATER RATES

By Geo. G. Earl

There is a general awakening of the people of the country upon the subject of the charges made by public service corporations, and a general widening of the scope of regulation of such charges by courts or commissions empowered to consider and revise them. As yet, the movement is in its infancy, but it has established a tendency toward a "square deal" for the patrons of these services and for their investors also.

If this tendency goes forward to its logical and desirable conclusion, exorbitant profits will not be permitted, but rates that guarantee a fair return will be established and maintained. These rates will not be permitted to be inequitable between different consumers, or different classes of consumers, or for different items of service.

Before this condition is brought about there will be necessarily a revision of rates charged by practically all public service corporations, which revision will be based upon a valuation of their properties, and an accounting of the cost of maintenance, depreciation and operation, properly sub-divided to establish the fair return for each logical division of the service. It will not be practicable, of course, to keep individual accounts to establish the cost of the service to each patron, and it would not be desirable to do so, since there would be accidents and incidents of individual service which are not within the individual's control, but would complicate accounting, render costs uncertain and unstable, and afford opportunity for favoritism that could not possibly be eliminated.

An ideal system of rates and of accounting for the establishment of rates, therefore, must determine the fair average cost of items of the same kind, and must collect that cost for each item entering into the service of each patron. The rates should not be based upon favoritism or the amount of good which the patron gets from the service, or the amount necessary to pay dividends upon excessive capitalization, though these are the only theories upon which many present rates can be defended.

Some public service corporations are charging exorbitant prices for some particular items of their service, or to some class of patrons, while they may not even be getting a fair return from the service as a whole; and as a frequent result have the enmity of those who are being taken advantage of without usually the good will or confidence of those who are benefiting by their discrimination. Very often the fact that certain items of service are being charged too high, and others too low, is not even recognized by those who have blindly followed precedent in rate schedules, which have been copied from one to another without regard to governing conditions or even correctness of original deductions.

When only fair returns are allowed, then risk must be eliminated and fair returns must also be practically guaranteed. In growing communities where the patrons are rapidly increasing, a fair rate at one time may easily become an exorbitant rate a few years later, when patronage increases, or a losing rate if prices or other conditions affecting the operation of the service change in the wrong direction. The rate, therefore, should be easily and equitably adjustable to meet these changing conditions, and a competent rating authority should have jurisdiction over the rates charged by all quasi-monopoly or public service corporations.

In order to determine rates that are fair according to service rendered, there must be a measure of service.

The water works system that attempts to work on a flat rate schedule cannot possibly do even approximate justice between its consumers, even those consumers who have the same rates applied to the same fixtures and conditions, because the personal element enters and cannot be eliminated, and the flat rate which averages right for a large number of families will be a rank injustice to the careful consumer, and an equal injustice to the water purveyor in the case of the careless consumer.

Gas, electric, and to some extent telephone companies, base their charges upon the quantity of service rendered and measured or recorded as it is given, and they are, as a rule, in a much more prosperous condition than water companies, being thus far also more free from attacks, although, so far as the writer can judge, their rates are more open to criticism on the ground of general or average overcharge than are water rates. A gas or electric company would not think of giving a flat rate service similar to the ordinary flat rate water service, yet the value of the gas and water delivered to the consumer per 1000 cubic feet runs nearly parallel.

Trials of flat rates for water as first reluctantly recommended by the writer for New Orleans very soon showed that the water consumption would go to over 300 gallons per capita per day under such a system, and that those consumers who were really fair in their use of water would have to pay over three times a fair price for the water which they actually used in order that their neighbors who wasted water might continue so to do, and that the very large consumers might get the benefit of the low cost per 1000 gallons which goes with a large output from the plant. In addition to this, there was looming up, as a necessity of the very early future, the expenditure of large amounts for increased pumping capacity, filters, etc., and enlargements of the distribution system that would not be necessary for fifteen or twenty years under fair use of water.

Under these conditions it was determined by the Sewerage and Water Board to meter all water consumers, even free consumers, and it became necessary to establish water rates for metered consumers. These rates had to be worked out to fit certain requirements of the law under which the Sewerage and Water Board was created, which requirements place a certain burden on the tax-payer as such, and a certain other burden on the rate-payer as such, and since these burdens as designated in this law are obviously improperly distributed, leaving the tax-payer to carry a lot of load which the rate-payer should shoulder, and the rate-payer to carry a weight which clearly belongs to the tax-payer, there seems to be no use in describing in detail the way in which the sub-division of these loads was actually applied.

It happens, it is true, that the actual load carried by the tax-payers and by the rate-payers is, and possibly always will be, about fair under the New Orleans law, but that is only an accident.

The only factor in the New Orleans water rates as now existing that is worthy, in the writer's judgment, of perpetuation consists in the complete division between that which is done for the individual consumer and that which is associated with the general service of all rate-payers and tax-payers.

Every water works keeps the account and makes the collection and reads the meter for the individual consumer. Most of them tap the water main for him. Some of them furnish the connection to the property line and maintain it, and some set and maintain his water meter. New Orleans does all of these things without any charge for placing the installation. These are an individual service. Their cost varies mostly with the size of the connection

and meter. It varies also with the length of the connection and the conditions under which it is laid. It is not practicable to charge to each individual consumer the exact cost of the service which is performed exclusively for him, nor would it be desirable or fair. You have human nature to deal with, and if you try to deal on the basis of exact individual cost, your consumer would say that he should not be penalized because he lived on the side of the street more remote from the water main, or because the paving or soil conditions are more difficult in his than another's locality, or the weather conditions were unfavorable when his work was put in or the forces employed on his construction were less judiciously employed, etc., etc. Therefore, instead of determinimg the specific cost of keeping each account and making each connection and placing, maintaining and renewing each service line and meter, with the infinite labor of such accounts and the unlimited chance for favoritism, for errors and for injustice which such a system of accounting would entail, you so classify your accounts that you can determine the average cost for each different sized connection and meter for the items above enumerated, or such of them as are applicable.

If a certain amount of annual payment is the average that is necessary to pay the interest on the first cost of a certain sized connection and meter, and to maintain it in operation, and to eventually renew it, and to read the meter and keep the accounts and make the collection, then that amount, or that amount plus a fair profit, is a fair charge for this particular item of service, regardless of whether any water is used through the connection or not, or of the amount of water, or of the character of or amount of plumbing inside of the premises, or the number of premises, or of the uses to which the water is put. Later, a tabulation covering the New Orleans preliminary estimate of these costs will be given.

Having thus established a charge or method of arriving at a charge which takes care of connections and meters and accounting and collection, let us see what other charges should be made and how they can be arrived at under ordinary conditions of water works practice.

The writer believes that a water works system must be regarded as a coöperative proposition. A separate system for large consumers or for small consumers or for fire protection would usually force higher costs for each. A given water works system has a given capacity, and every consumer of water appropriates a certain proportion of that capacity, and each by his proportionate consumption hastens the date when an enlargement of the system will be required

Each in proportion to his use of water consumes fuel and coagulant, if these are used, and gets a proportionate benefit from every expenditure required to keep the system in operation. Having eliminated the cost of doing business with each, then, through the service charge, should they not all pay for the service received exactly in proportion to the amount of that service, *i. e.*, to the amount of their consumption of water?

If you can ascertain the exact amount of water that you can sell, and the total cost of operating and maintaining the water works system to the consumer's tap, the price per 1000 gallons of water ought to be a question of division; and since the consumer pays, in his service charge, the cost of doing business with him, he should be regarded upon the same basis as the patron of a "nickel in the slot" machine, to whom each nickel brings an equal return. There is less reason for one customer to get 300 gallons of water for his nickel where another gets 1000 than there would be for the large property owner to pay a lower percentage of tax upon his property than the small one, or the owner of twenty dogs to pay a less tax per dog than the owner of one dog, because in these cases the cost of collection and accounting does enter and is less for the owner of much property or many dogs than for their less opulent fellow citizens.

Let us now take an example and assume the necessary data and see whether a logical and easily adjustable system of making a water rate that shall be always fair to everyone can be devised.

Let us suppose that New Orleans instead of passing her rather unusual and special law had done the more usual thing—that is authorized a board to use the city's credit for the construction of a water works system, with authority to issue bonds to the amount of the cost of the system, plus its going value until it could maintain itself, and to make water rates that would meet the interest on outstanding bonds, and maintain, operate and eventually renew the plant.

Let us assume, first, that we are going to do fairly between the tax-payer and the rate-payer; in other words, that the citizen pays out of his taxes and not out of his water rates for those public and charitable uses of water by which he benefits as a tax-payer whether he is a rate-payer or not. If the public authorities and departments and charitable institutions are themselves rate-payers to the water department on the same basis as other consumers, their interest in the economical uses of water will be greater. So from the general

tax fund there should be budgeted to each such department in some manner an amount sufficient to meet its water rates.

Let us assume now about the existing New Orleans data and see if we can arrange a system of division of actual expenditure from which we can determine:

1. A fair fire hydrant rental.
2. A fair service charge for each given size meter and connection.
3. A fair price per 1000 gallons of water.
4. A fair amount to be raised by taxation.

Assume total cost of water works system	$8,500,000
Of which meters and connections to property line cost	$750,000
Assume that remainder of system is one-fourth for fire protection	1,940,000
and three-fourths for other uses	5,810,000

The population is 340,000.

Roughly, there are 515 miles of mains, and 5000 fire hydrants, and now in use 25,000 meters and connections, out of a possible 60,000 required to serve the 80,000 premises of the city.

	Gallons per day
Assume sum of all meter readings to private consumers equals	7,000,000
Assume under-registration 20 per cent	1,400,000
Assume sum of all meter readings to public and charitable institutions	3,000,000
Under registration, 20 per cent	600,000
Assume use through fire hydrants by Fire Department and Department of Public Works	2,000,000
Assume leakage waste and flushing out on 515 miles of mains	2,000,000
Average total present consumption	16,000,000
Nominal capacity of plant	45,000,000
Maximum capacity of filters	67,000,000
Pumping capacity, into distribution system	100,000,000
Capacity distribution system at effective pressure	80,000,000

It will appear from the above that the present water works system is greatly in excess of the needs of its present patrons, and if the consumers of the 7,000,000 gallons of water which is recorded to paying consumers had to pay water rates that would cover interest, depreciation and all expenses of maintenance and operation, their bills would be so high that they could not afford to take the service.

Assume the expense bill to be met to be as follows:

1. Interest and depreciation on cost necessary for general system—4½ per cent on $5,810,000	$261,000
2. Interest and depreciation on additional cost due to fire system—4½ per cent on $1,940,000	87,000
3. Interest and depreciation on cost of meters and connection, and cost of maintenance of same 25,000, cost $750,000—say	60,000
4. Cost of meter reading and collection and accounting on water rates—say	40,000
5. Cost of maintenance of distribution system	50,000
6. Cost of maintenance of fire hydrants and connections to same	10,000
7. Cost of maintenance and operation of the pumping and purification plant, say output cost $70,000, capacity cost $80,000—total	150,000
Total	$658,000

These figures are assumed, but are sufficiently within range of the truth to illustrate the method and effect of the division of expense contemplated.

To be charged to fire hydrants and fire protection and other public uses of water through hydrants we have:

All of Item 2	$87,000
All of Item 6	10,000
One-fourth of Item 5	12,500
Two-fourteenths of output cost and one-fourth of capacity cost of Item 7	10,000 20,000
	$139,500

$$\frac{\$139{,}500}{5{,}000} = \$28 \text{ per hydrant} = 41 \text{ cents per capita of population.}$$

To be charged as a service charge fairly pro-rated to each different sized meter and connection, we have:

All of Item 3	$60,000
All of Item 4	40,000
	$100,000

To distribute this item between public and private consumers correctly would require the application of the proper "service charge" to each service. To approximate a division, however, for this paper

we will assume a division in proportion to consumption as reaching approximately the same result, *i.e.*:

$100,000 \times 0.3 = \$30,000 =$ public consumers.
$100,000 \times 0.7 = 70,000 =$ private consumers.

To be charged to metered consumers against 10,000,000 gallons per day of meter record you have 12,000,000 gallons of water, or twelve-fourteenths of the supply which is usefully employed, since leakage and waste from and flushing out of the distribution system have lost 2,000,000 of the total 16,000,000 gallons of supply. To this account must be charged as follows:

All of Item 1	$261,000
Three-fourths of Item 5	37,500
Twelve-fourteenths of output cost and three-fourths of capacity cost of Item 7	60,000 60,000
Total water charges	$418,500

$418,500 \times 0.3 = \$125,550 =$ public consumers.
$418,500 \times 0.7 = 292,950 =$ private consumers.

Dividing these expenses between the tax-payer and the rate-payer, we have as follows:

	FROM FIRE HYDRANTS	FROM SERVICE CHARGES	FROM WATER CHARGES	TOTAL
From tax-payers	$139,500	$ 30,000	$125,550	$295,050
From rate-payers		70,000	292,950	362,950
Totals	$139,500	$100,000	$418,500	$658,000

The total from water charges of $418,500 applied to a 10,000,000 gallon consumption recorded through meters requires a rate per 1000 gallons of 11.5 cents, which is very close to the average rate now actually collected from consumers of pay water, because while the New Orleans rate is 10 cents there are enough small consumers using less than their minimum allowance of 40,000 gallons per year to raise the average payment from the 10 cents per 1000 gallons, as now fixed, to about $12\frac{1}{2}$ cents.

The $362,950 total payments from rate-payers, and the $295,050 total payments from tax-payers are just about equal to their present payment under existing rate.

The following tabulation shows the values that have been assumed at New Orleans for determining the service charge for ordinary connections and meters. It will take several years to determine the adequacy of these service charges. The tabulation is submitted as a system of blanks to be correctly filled for each special case:

Material of Service.....	LEAD					CAST IRON			
Size Meter and connection	¾"	1"	1"	1½"	2"	3"	4"	6"	8"
Cost of connection..	$10	$10	$15	$45	$70	$ 60	$ 60	$ 90	$120
Cost meter in place .	15	20	25	45	65	100	200	400	650
Total cost inst'la... ...	$25	$30	$40	$90	$135	$160	$260	$490	$770
Annual cost to pay interest and to maintain and renew services	$1.00	$1.00	$1.50	$2.00	$2.75	$4.25	$6.00	$9.00	$12.00
Annual cost to pay interest and depreciation and renew meters	1.50	2.00	2.50	4.50	6.50	10.00	20.00	40.00	65.00
Annual cost to cover meter reading, accounting and collection of water rates.....	1.50	2.00	2.50	4.00	5.25	7.75	10.00	15.00	20.00
Total annual charge....	$4.00	$5.00	$6.50	$10.50	$14.50	$22.00	$36.00	$64.00	$97.00

With an established tabulation like the above, only much more in detail, comparisons on a comparable basis of one city with another could be made, and all kinds of adjustments for changes in size of connections and meters could be made as required and rates for a small meter on a large service, or a detector by-pass meter on a fire service, or any other combination desired.

When property is vacant in New Orleans the service charge is remitted, otherwise the city assumes that the property owner who had the city invest anywhere from $25 to $770 in a meter and connection to furnish his property with water was in earnest when he applied for his connection, and he is required to pay his service charge whether he uses water or not, except that his service or meter can be removed if he reimburses the city for the cost of the original investment, plus the cost of the removal less the value of the material removed less a fair discount for the time during which the service has been in actual use.

Eventually we may try to get a tabulation of average costs to cover removals and salvage, etc., or it may prove best to hold the service charge high enough to cover the cost also of such changes in size of meter or connection as may be required, or changes in location of connection, etc., where a property is destroyed and rebuilt upon different plans or for different uses.

Your next blank is the cost (or the cost plus a fair profit) per 1000 gallons of water recorded as passing through the consumer's meter, which may be anything, say from 30 cents to 3 cents. It seems to be 11.5 cents in New Orleans now; when the consumption reaches 45,000,000 gallons it will probably be under 6 cents. It is recommended to hold it for the present to 10 cents, as additional consumption will soon equalize this rate. Then because of under-registration of meters when the stream passing them is too small to register, you can properly establish a minimum amount of pay water for each given sized meter. These amounts as recommended for New Orleans, for ordinary meters, are as follows per annum, being the service charge, plus 10 cents per 1000 gallons for the specified amount of water:

SIZE OF METER AND CONNECTION	LIMITATION OF SERVICE	QUANTITY OF WATER PER YEAR ALLOWED AT STATED MINIMUM RATE	COST PER YEAR	COST PER 1000 GALS.
inches		*gallons*		
$\frac{5}{8}$	Serving not over two persons and rooms	10,000	$ 5.00	$0.50
$\frac{5}{8}$	Serving not over three persons and rooms	20,000	6.00	0.30
$\frac{5}{8}$	Serving not over four persons and rooms	30,000	7.00	0.23⅓
$\frac{5}{8}$	No limitation	40,000	8.00	0.20
$\frac{3}{4}$	No limitation	50,000	10.00	0.20
1	No limitation	65,000	13.00	0.20
1½	No limitation	105,000	20.50	0.20
2	No limitation	145,000	29.00	0.20
3	No limitation	220,000	44.00	0.20
4	No limitation	360,000	72.00	0.20
6	No limitation	635,000	127.00	0.20
8	No limitation	970,000	194.00	0.20

As consumption increases beyond the amounts stated the total cost per 1000 gallons is automatically decreased until in the case of the very large consumer the "service charge" becomes so small a factor that the actual total payment approximates but never quite falls to the 10 cent actual "water rate."

If a compound meter is used, or any kind of reliable detector, the size of the by-pass meter should govern the minimum amount of water to be paid for, and size of main line the service charge. If under-registration on small streams could be avoided there would be no excuse for any minimum rate of pay water at all.

It will be noted that in the above schedule of water rates the term "service charge" does not appear at all; and in framing the printed charges it may be best to present just as few points for discussion and criticism as possible. A minimum annual bill for a given size meter and connection, with a flat price per 1000 gallons of water in excess of a stipulated quantity, will probably best meet this condition, said minimum being applicable just as well to a metered fire service as to any other form of service.

The writer's idea in stating the rates as above, however, is that they are in the simplest possible form, and he would keep their method of creation close for explanation to any citizen who wished to understand the reason for them or for the correction of any inequity which, exactly as stated, they might possibly work in exceptional cases.

Having applied the proper service and water charges to every possible consumer that it is practicable to meter, including all public institutions, the water works has only to collect the fair fire hydrant rental, and the city to adjust the tax rate to reimburse itself for water rates to be paid by taxation.

The figures given throughout remember must be right, and just as fast as experience warrants they must be changed and kept right. No one can fairly complain. The small consumer will not care to because he is usually benefited. The large consumer in some cases will have his bill raised, but in such cases he ought to be very grateful that the new rate is not retroactive.

Public and charitable institutions supported by taxation would be metered and would pay the same water rates as private consumers, and would get money to pay them from the tax fund by budget. Their uses of water could then be compared with each other, with similar services elsewhere, and with private consumers, and they would have the same interest as other consumers in keeping their consumption within reasonable limits, while the public who paid in taxes for this and for water for fire hydrant uses could know exactly the status of these uses, and would be certain that given a fair valuation of property the contribution of each property through taxation was an equitable proportion.

The contribution by taxation for New Orleans now, under the above scheme, would be 0.00123 per cent on the assessed value of $240,000,000 in which every tax-payer would share, every dollar of which would go to purposes for which tax-payers, independent of whether they were rate-payers or not, should contribute, this contribution being as equitable at least as those they now make for other public purposes.

The example here is of an over-built system at the very inception of its operation, when its consumption is under one-third of its easy capacity. As a consequence its capacity cost greatly over-balances its output costs, and the rate that has to be charged per 1000 gallons of water is high, and big consumers especially complain.

The system was designed to serve a growing city of 340,000 population at the date of its completion. In the light of water consumption elsewhere, and with uncertainty as to whether the all meter system could be carried through, 45,000,000 gallons per day did not seem too high a capacity to build, especially in view of the fact that the old water works company, with only 7000 connections on 125 miles of mains often pumped over 20,000,000 gallons, and the new system was to cover 500 miles of mains, upon which there were 80,000 premises.

Looking forward a few years, and assuming an average daily consumption of 45,000,000 gallons, let us see about where water rates made up as advocated would go, assuming $800,000 spent in construction, in minor extensions to the distribution system, and increased connections from 25,000 to 75,000 and fire hydrants to 6000, with following division of water consumption:

Private consumers' meter readings, say	27,000,000
Private consumers' under-registration, 20 per cent	5,400,000
Public consumers' meter readings, say	5,000,000
Public consumers' under-registration, 20 per cent	1,000,000
Uses through fire hydrants, say	3,600,000
Waste and flushing distribution system, say	3,000,000
Total consumption, daily average	45,000,000

Working out as before upon the above assumption and tabulating costs chargeable to tax-payers and rate-payers, we have, as follows:

	FOR HYDRANTS	FOR SERVICES	FOR WATER	TOTAL
Tax-payers	$173,800	$ 43,750	$ 87,200	$304,750
Rate-payers		236,250	473,000	709,250
Total	$173,800	$280,000	$560,200	$1,014,000

By this time the city will have grown in population to, say, 500,000 at least. The assessed valuation will have increased from $240,000,000 to, say, $430,000,000, and the tax-payer's rate will have dropped from 0.00123 per cent to below 0.0007. The rate per 1000 gallons of water should have dropped gradually from 11.5 cents to 4.8 cents, while the price per fire hydrant upon the assumptions made remains about the same, and the cost per capita for fire protection would have decreased from 41 cents to 35 cents per year.

Of course, as the time approaches when the nominal capacity of the plant is fully utilized it would be best to hold up all tax-payers' and rate-payers' rates sufficiently high to average off the increase in same that would otherwise come when additional plant had to be constructed. It is easier and more popular to lower rates than to raise them; so the water works manager should look ahead enough to keep his rates a little on the down-grade even through peaks of considerable new construction that would otherwise necessitate an increase.

Specific instances of rates are best as illustration, so let us consider a typical modern house in New Orleans under fair rates and under the old water works company's rates, viz: a 12-room house, with 5 persons, 18 openings, 50-foot front lot, sprinkling privilege, etc., and assume its actual water consumption at 70,000 gallons a year, ¾-inch meter and connection; assessed at $5000. On the suggested plan the bill would be made up as follows:

Service charge	$4.00
70,000 gallons water consumption at 10¢	7.00
Total water bill	$11.00
Tax 0.00123 per cent on $5,000	6.15
Grand total tax and water bill	$17.15
Cost per 1000 gallons of total consumption, including tax	$0.25
Cost per 1000 gallons of total consumption, excluding tax	0.16

With flat rates in vogue by the old water works company prior to 1900 this house, using this quantity of water, would have had to pay an annual water bill of $106, amounting to $1.50 per 1000 gallons.

After this company had been relieved of its franchise by the courts on the grounds of inequitable rates or discrimination this house could have had a flat rate of $74 a year, or $1.06 per 1000 gallons, or it could have paid a high price for and ordered a meter installed, and by paying 25 cents per 1000 gallons for not less than 20,000 gallons a month it could have had water for $60 a year or 86 cents per 1000 gallons for water actually required.

With this company the consumer paid $5 for a tap and paid a plumber to make and maintain his connection.

Notwithstanding these rates this company was only getting 6 cents per 1000 gallons in total revenue for all of the water it pumped because nearly all of its consumers were on flat rates, and most of them had a grouch against the company and tried to see how much water they could waste, overlooking the fact that this waste was what made the company's pressure so bad that a connection from its mains often would not feed the second story of houses remote from the pumping station. Some of these consumers were actually getting their money's worth in quantity of water whether they had use for it or not, and some few of those who really had use for the quantity which they were drawing, *i. e.*, very large consumers, are paying now a higher water bill than they paid to the old company and complaining because the city will not give them a 5-cent rate.

The writer has made a comparative study for New Orleans to see about how much difference there really would be in its case between all meters and the ordinary flat rate schedule, and he is convinced that, assuming every premises in the city today connected with a water works system that was constructed and kept ten years ahead of its capacity requirements, there would be an annual saving by the meter system to the tax-payers and rate-payers of the city all told of at least $450,000 a year, or over $1200 a day. With present population, with meters the consumption would be, say, 28,000,000, and with flat rates the consumption would be at least 80,000,000 gallons per day, and the large consumers could have a very low price per 1000 gallons of water, while the conservative small consumer who prevented waste would pay for his neighbor's waste and for the large consumers' advantage over three times his present bill to cover extra coal and coagulant and extra labor and interest requirements

for unnecessary extensions to the water works system, in which luxury the tax-payer would share.

The small consumers and small tax-payers are in the majority in all of our cities, and they are beginning to study the rates which they are paying and to ask a reason for any seeming inequity and whenever they find a real or fancied injustice to themselves they are agitating against it with voice and vote so that in some cases the reaction is going to the opposite extreme and certain classes of small consumers are getting rates below the fair cost of the service rendered to them.

No one now would defend a railroad rebate; it is recognized as an evil which has worked untold injustice, and is now outlawed. The shipper who received no rebate was being taxed a higher rate for the benefit of the rebated shipper. This is only another way of saying that one paid more than a fair return for the service rendered, and the other less, and reduces itself to this, viz: "*That no single item of service rendered by a quasi-monopoly or public service corporation can be charged for at a price higher than the fair average cost of all of the items of this kind performed by it, plus a reasonable profit thereon.*"

The power to limit gross receipts to a fair return is now admitted everywhere. If the gross receipts are reasonable but certain items therein are charged at an excessive price, then the class of patrons paying for these items are obviously being discriminated against in favor of some other patrons, which is exactly what rebating is, a tax upon some to their detriment for the benefit of others.

The usual telephone rate sheet in almost any city seems to present aggravated examples of rates per item of service which bear no relation to the cost of the service rendered in said items. These rates as a whole may not yield more than a fair return, but if they do not then the tax which they impose upon some for the benefit of others seems to be excessive.

Take, for instance, a residence rate for an unlimited service, and direct line, which costs, say, $48 a year. One residence may contain 20 people who keep the phone busy constantly, say with an average of 20 calls a day. Another residence contains only six persons and has six calls average per day. Residence No. 2 has to pay exactly the same as No. 1 for one-third of the service. Again, take house No. 2 with six people and six calls a day, but instead of one family assume two families living together each of whom want a name in the telephone book, same equipment, same number of calls, but they are confronted with this: "extra name in book, $12 per year," of

which about $11.75 is profit to the telephone company on an investment of nothing. Or again, house No. 2, with a partial invalid at the head of the house wants an extension set upstairs, which cannot cost over $5 to install nor over 50 cents a year to maintain, but it costs, once more, $12 a year, or say $11.50 a year income on a $5 investment.

Obviously, these charges are based upon the necessity of the patrons and not in any sense or degree upon the cost of the item of service to the company, and in each case they help to pay for an undercharge which is made to some other class of customers, or else they swell an unreasonable profit.

In the writer's view there is a great procession forming in this country; it carries numerous banners with many mottoes: the banner in front cries for the "square deal;" another calls for the "conservation of natural resources;" another says "no more rebates;" another, "equal rights to all, special privileges to none," and so on down the line, in a thousand different wordings, invented by a public conscience which has been awakened in various ways, often possibly by personal failure in an opposite course, to a general belief that after all, "Honesty is the best policy."

The water works fraternity have much to gain and nothing to lose by joining this procession; water rates are, generally speaking and as a whole low—they are often inequitable, and so subject to destructive attack. Would it not be better to give some real study to the question of how to establish and maintain a fair rate so certainly that the courts and even the majority of the people will recognize it, and thereby get into a position that will assure, through universal metering, reduced total payments by rate-payers and tax-payers, and at the same time fair returns for water service, and in so doing promote stability in water enterprises and the good will of the great majority of the consumers so far at least as uniformly fair treatment can induce good will?

The "square deal" army is forming in every city and hamlet and cross road in the country. Those who are wise enough to paste Mr. Hubbard's "Do it now" motto over their hat bands can safely mingle with this procession—may even "follow it in front," while those that believe that they can reap a permanent advantage by an opposite course are more than tempting fate.

The writer does not claim that he has worked out the system perfectly in the example assumed, but he asks earnest consideration of the principles involved as suggesting a general line along which a

logical rate system can be established which will allow of comparisons between rates in different cities, through the comparison of the items entering into their determination, as ascertained by such a uniform division of accounts as would be required to serve as a basis for the determination of rates.

DISCUSSION

PRESIDENT ALVORD: Your President takes great pride to himself in the fact that he discovered Mr. Earl wrestling with this problem in a somewhat novel and original way and persuaded him to write this paper. We have had rate discussions here for quite a number of years past; but I take it that we are still only beginning to understand the subject. This paper of Mr. Earl's seems to me to be an unusual one in many respects, presenting an unusual problem which Mr. Earl has had to face and which he has worked out with a great deal of originality.

MR. LEISEN: I have had occasion recently to make an investigation on this question of water rates in Louisville, and it has been interesting to me to listen to Mr. Earl's paper and note that in some respects at least our ideas have run along similar channels. The whole question of meter rates I suppose is, like the tariff, a local issue, because there are certain conditions in every city that have to be met in a certain way. At the outset I might say that in Louisville the law creating the board of waterworks which operates the Louisville water company, requires the company to deliver free water for all civic and municipal purposes, and for fire protection; so that making a proportional charge of the total cost for that service is out of the question. With your indulgence I will read the report which was prepared for submission to the Louisville Waterworks Board. There are some things in it which of course may not be of direct interest to this association; but I think I can get at the question more directly by reading this paper in full, or nearly so, rather than by trying to give a summary of it.

I have endeavored to treat the subject along the same lines that Mr. Earl has. I am willing to confess that I have done it in a very much cruder manner and have not gone into the refinement of the situation to anything like the degree that Mr. Earl has; in other words, I have made a short cut to reach the same goal. I might say that I believe, and I think all the members of our board believe now that the water rates at Louisville should be reduced. Our meter rates taken at the

1000-gallon rate are not excessive as compared with most cities, and our flat rate scale does not seem to be excessive; but the fact remains that when a bill comes in to the consumer he is paying a great deal higher rate for all of the privileges which an ordinary household requires than is common to a very large majority of the cities of this country, particularly those having municipal plants. Out of 35,000 services we only have 2800 meters; and that it seems to me gives us an exceptional opportunity to be able to introduce a meter rate, and at the same time promise a material reduction in the rates to almost every consumer in the city.

Without any further preliminary remarks I will read the report as it was presented to our board.

REPORT ON METER RATES MARCH 10, 1911.

LOUISVILLE, KY., March 10, 1911.

MR. CHARLES F. GRAINGER,
President, Board of Water Works.

Dear Sir: Assuming that a radical change will be made in the water rates (commencing January 1, 1912,) and believing that the sale of water by meter measurement is the only rational method under which the water company can operate on a strictly scientific basis, and at the same time deal justly with all consumers, I wish to submit the following facts and figures which have been evolved from a careful study of the subject.

The primary, and most convincing argument in favor of selling all water by meter measurement is that the consumer pays only for what he actually uses, and in arranging for a meter schedule of rates this fact should be kept constantly in mind, and any scheme however advantageous or simple, which departs from this principle will be open to more or less reasonable objection.

No system of rates which ignores the necessity for a fixed minimum income from every service, can successfully withstand the test of commercial requirements without making the unit rate for water excessively high, and thereby working a hardship on the large consumer, but on the other hand the practice of establishing a minimum rate which permits a predetermined quantity of water to be used under that rate,—a system in vogue in this, and many other cities,—is objectionable for the reason that it nullifies the primal argument advanced for the adoption of the meter, by deliberately charging the consumer for water which is not consumed in the majority of cases. As an instance, we charge a minimum rate of $36.50 per annum, which permits the consumption of 700 gallons per day. If the consumer only uses 300 gallons per day,—an amount which experience has shown to be ample for the average dwelling,—he is charged for 57 per cent more water than he uses.

Another undesirable feature in the tariff of meter rates prevailing in many cities is the sliding scale which discriminates against the small consumer, and, although commercially reasonable from the view point of the water department, which can afford to supply in wholesale quantities at reduced rates, it is nevertheless unjust to the individual consumer.

Assuming that it is desirable to place all services on a metered basis, and as this appears to be an opportune time to inaugurate a radical departure in the method of charging, and the rates for supplying water, a scheme has been devised which it is believed will obviate all of the objectionable features referred to, forestall any possible charge of discrimination; insure a substantial reduction in the water rates of nearly all consumers; provide adequate revenue for the operation of the water company, and at the same time offer to manufacturers a rate so low as to make it an inducement to them to discard the use of well water in favor of the city supply.

The first requisite of a proper system of rating is the production of a revenue sufficient for the operations of the plant in all its ramifications: The operating expenses of the Water Company for 1910 were as follows:

Overhead Expenses		
Administrative and revenue	$56,106 87	
General expenses	42,813.77	
Interest	74,425 28	$173,345 92
Production Expenses		
Pumpage	$46,498 54	
Filtration	28,282.40	
General operations	48,239.09	$123,020.03
		$296,365.95

Assuming that the expenses for the year 1912 will be approximately the same as above, and estimating the amount necessary for extensions, improvements, etc., we have the following:

Operating Expenses		
Overhead expenses	$175,000.00	
Production expenses	125,000.00	$300,000.00
Construction Expenses		
Extensions of mains—10 miles	$40,000.00	
Meters	40,000 00	
Other improvements	20,000.00	
Reserve for depreciation	25,000.00	
Surplus and incidentals	50,000.00	$175,000.00
Total annual expenses which equal the revenue required		$475,000.00

A meter rate must therefore be arranged in such a manner as to produce not less than $475,000 annually.

The overhead expenses amounting to $175,000 exist independent of the quantity of water sold, and these fixed overhead charges should be met by a fixed income, and this it is proposed to do by means of a "Service Charge," on each meter installed. There are approximately 30,000 services in active use, and dividing this number into $175,000 would give $5.83 to be charged against each service. For convenience it is proposed to establish this "Service Charge" at

$6.00 per annum for each $\frac{5}{8}$-inch meter; $9 for $\frac{3}{4}$-inch; $12 for 1-inch; $24 for 2-inch, and on up to $72 for a 6-inch meter. If every tap were metered this "Service Charge" would produce sufficient revenue to meet all fixed overhead charges, and leave a safe contingent profit.

The object in increasing the service charge in proportion to the size of the meter is two fold: It makes a more equitable distribution of the charge, proportioning it to the service actually rendered, and it deters consumers from applying for a larger meter than is actually required. This "Service Charge" would not cover the cost of any water consumed, but would take the place of a meter rental, and serve the equivalent purpose of a "minimum charge." It covers the value of what is generally designated as a "readiness to serve" charge, and being based on the proportionate cost of fixed overhead charges, is figured on logical reasoning, and is not a mere arbitrary or haphazard charge.

With this "Service Charge" established as outlined herein, the water can be furnished to every consumer at exactly the same rate, regardless of whether he uses one thousand gallons or one million gallons, and this rate can be fixed at *five* cents per thousand gallons and within a few years it probably can be reduced to four cents per thousand gallons, in which event we may claim, without fear of contradiction, that we are furnishing the cheapest water of any city in the country having similar conditions to contend with.

To illustrate how this rate will work out in actual practice, a few cases are given with the old and the new rates:

Louisville and Nashville Railroad Company--1910

Present rate—17 meters 392,426,232 gallons		$24,371.31
Proposed rate—service charge	$ 882.00	
Proposed 392,426,232 gallons at 5 cents	19,621.31	20,503.31
Reduction—16 per cent		$3,868.00

Louisville Railway Company—1910

Present rate—21 meters 146,137,720 gallons		$9,594.01
Proposed—Service Charge	$ 696.00	
Proposed 146,137,720 gallons at 5 cents	7,306.88	8,002.88
Reduction—16 per cent		1,591.13

Dwelling—12—14 rooms—$\frac{3}{4}$ inch Meter

Present rate—700 gallons per day		$36.50
Proposed rate—Service charge	$9.00	
700 gallons per day-255,500 gallons at 5 cents	12.77	21.77
Reduction—40 per cent		$14.75

Dwelling—7 rooms—30 foot lot

Present rate—General convenience and sprinkling		$26.10
Proposed rate—service charge	$6.00	
300 gallons per day 109,500 gallons at 5 cents	5.47	11.47
Reduction—55 per cent		14.63

The regular service charge of $6 per annum for a ¾-inch meter, with a reasonable water consumption would be a benefit only to dwellings whose flat or schedule rate exceeds $10 per annum, and in order to provide for metering very small dwellings it is suggested that where the present rate is from $7.50 to $10 per annum, there shall be installed a so-called ½-inch meter with a service charge of $4.50, and where the rate is under $7.50 there shall be installed a so-called ⅝-inch meter, with a service charge of $3 per year. The latter charge would provide a rate of $4.82 with 100 gallons consumption per day, or $3.91 with 50 gallons per day.

There is no guess work in determining the rate which will have to be established to provide the revenue necessary for the operations of the plant: All figures have been derived from the conditions existing in 1910, the only estimates being the probable quantity of water which will be consumed through meters, and this is taken on a basis so conservative as to insure the final result being in excess of the estimates. The average daily quantity to each metered tap in 1910 was 2,634 gallons, and for each non-metered tap 538 gallons. In calculating the revenue to be derived from metering all of the present non-metered services, only 275 gallons per tap has been taken as the average quantity to be paid for. Or, from a total present daily consumption of 22,131,000 gallons only 15,140,000 gallons or 68 per cent is estimated as revenue-producing consumption, the remaining 32 per cent being allowed for fire service, street flushing, and waste.

The following is the total estimated revenue which would accrue under the proposed schedule of rates, with every service metered, based on the present number of services:

SERVICE CHARGE

Present Metered Service

960—⅝ inch at $6.00	$5,760.00	
321—¾ inch at 9.00	2,889.00	
802—1 inch at 12.00	9,624.00	
244—1½ inch at 18.00	4,392.00	
283—2 inch at 24.00	6,792.00	
120—3 inch at 36.00	4,320.00	
74—4 inch at 48.00	3,552.00	
43—6 inch at 72.00	3,096.00	$40,425.00

Proposed Meters

5,000—¾ inch at 9.00	$45,000.00	
15,000—⅝ inch at 6.00	90,000.00	
4,000—½ inch at 4.50	18,000.00	
3,153—¾ inch at 3.00	9,459.00	$162,459.00
30,000 Metered services. Total service charge		$202,884.00

WATER SUPPLY REVENUE

Present Metered Service

2,847 meters—2,741,000,000 gallons at 5 cents	$137,050.00

Proposed Meters

5,000—400 gallons per day..	730,000,000 gallons		
15,000—300 gallons per day..	1,642,500,000 gallons		
4,000—200 gallons per day..	292,000,000 gallons		
3,153—100 gallons per day..	115,500,000 gallons		
27,153 meters	2,780,000,000 gallons	at 5 cents	139,000.00
			$478,934.00
Other revenue			$6,066.00
Total estimated revenue			$485,000.00

It should be borne in mind in considering this proposition that all of the estimates are founded on the number of consumers on record for 1910, no attempt having been made to include the normal increase which two years is sure to produce. It must be recognized also that the change to a metered system will of necessity be a gradual one and will probably require four or five years for its complete development, during which time the revenue will be reduced by degrees only, on account of the proposed change in rates, but will be constantly increasing by virtue of the normal growth of business. For this reason and also because of the conservative nature of the estimate submitted, it seems fair to assume that the four cent rate may be realized in a very few years.

Summarizing the merits of the proposition, the following features appeal to both reason and a proper sense of justice: It furnishes water at the lowest rate consistent with the requirements of the plant; it makes the same rate to every one for the water consumed, while through the medium of the "service charge" it gives the large consumer the advantage to which he is entitled by the practical absorption of this charge; it places the burden of the service charge exactly where it belongs for the reason that it costs the same to be prepared to furnish water through a given size meter to the consumer who uses but 200 gallons per day as it does to the one who uses 2000 gallons, while it does cost more to be prepared to furnish the quantity of water which would be normally consumed through a six inch meter, than would be the case with a $\frac{5}{8}$-inch service, and finally it provides a system of rates based on the operating expenses, which can be readily adjusted to meet varying conditions without affecting its underlying principle.

I would earnestly recommend the adoption of the proposed system of rates, as I feel assured that in its application it will prove to be the most practical, most satisfactory and most successful method in use in any city in the country.

Very respectfully,

THEODORE A. LEISEN,
Chief Engineer and Superintendent.

In Louisville well water is very easily obtained, and quite a large proportion of our manufacturers have wells. Quite a number of our consumers also, unfortunately both for them and the health of the city, have access to wells. I believe that true business policy would

make it advisable to endeavor to furnish them water from the municipal supply only, as wells in the city show evidences of pollution.

MR. BEMIS: Unfortunately I was seated so far back during the reading of the first paper because I did not come in till it was partly finished, that I am not in a position to discuss it directly; but there are a few general remarks that I would like to make. It is a pretty big subject to attempt to handle in a five minute discussion. I devoted an article to it recently in one of the engineering journals which some of you may have seen; so I will not attempt to review the ground taken in that paper.

I would like to correct one statement of Mr. Earl's. If I heard him aright I understood him to say that he would assume, or had assumed for the purposes of that paper 20 per cent under-registration of meters particularly the residence meters in houses. I had charge of over 75,000 meters in Cleveland, and last year there were about 78,000 or 79,000. There is actually accounted for in Cleveland over 85 per cent of all the water that leaves the station. That proportion of it goes through meters. Another 3 per cent is used and accounted for, leaving as unaccounted for in 1910 only 12 per cent.

The under-registration of the meters is nowhere near 20 per cent. I do not believe that the under-registration in cities where they are taken care of properly is over 3 per cent. I doubt if it amounts to 2 per cent. Of course there is all the difference in the world in meter policies. It is vastly important to buy thoroughly up-to-date and accurate meters, durable meters. It is vitally important to keep them in proper condition after they are purchased, by frequent repairs. But that being done, I do not want the impression to get abroad that there is any such under-registration of meters to be feared as might perhaps be implied even with regard to house meters.

Now with respect to the general problem, I think the water situation, for municipal supplies particularly, is in a very formative position at the present time with regard to rates, a position of very vital importance with respect to the future, because we are now turning from flat rates to the meter system and the rates that we are now putting into effect will have much influence in the future. It is a period of departure in America regarding the whole meter situation and in regard to the matter of rates.

Now I am not here to contend that we should get less revenue than we are getting in water departments. The question is rather as to the apportionment of the revenue to the different kinds of service. I

recognize that there are conditions under which it may be necessary to charge a lower rate for large use than for small, for manufacturing than for house use. I do not think it is necessary in most cities to have more than two rates; one for the first 2000 gallons per month, and the rest for all in excess of that. I think that the moment you attempt half a dozen rates or sliding steps in your scale you will give one manufacturer an opportunity to get a lower rate than another on just a little smaller business, which is rather contrary to our usual theories of public policy, particularly in publicly owned plants; but whether with regard to water there should be two rates or not is a question that you will have to think out. There may be such cases. At least we must bear this in mind, that in seeking to have a lower rate for large users of water—which is the rule perhaps in some degree in private business—we are cutting out for ourselves in municipally operated plants a very big proposition, a proposition bigger than we realize, for we are going against the whole theory of government. I am referring now particularly to publicly owned plants. The whole theory of government is expressed in giving the same rate to all, the same rate for postage stamps whether you buy a single stamp or buy a thousand; the same charge for internal revenue stamps whether you buy one or a thousand; the same for liquor stamps or cigar stamps or stamps for any other articles under internal revenue; the same rate of taxation for the large and small property owner. It is only in case of slower or otherwise inferior second and third class service, or of a direct educational object through the lowest possible distribution of papers and magazines, that a lower rate is given. The point is that the national government makes no difference in charge because of mere quantities sold or transported. It is, therefore, a very serious problem to go against the general tendency of modern governmental social philosophy, and only to be justified by large necessities in individual cases. At the same time I recognize that it is justified in the minds of many from a consideration of the fact that the service costs less. Before we touch on that let us note, however, that that same thing is true in gas; and yet the gas companies the world over, with very few exceptions, charge the same rate for all uses, both publicly and privately owned, both in this country and in Europe; and they have been in the meter business much longer than the water departments.

Electric light is different, but electric light has to contend with the lack of storage facilities, which does not exist so much with water. Again, if we were going to apply this theory to cost we must bear in

mind that it costs much more to furnish service on a street where there are two or three consumers than where there are a good many in the same place. It costs a great deal more to furnish service two miles away from the pumping station than it does near it. Then again we must bear in mind that after all private business is not all run on this theory of fixing prices by the companies. Your retail merchant sells you a shirt for the same price at 9 o'clock at night when he is keeping open at a loss and only selling a few things that he did during the day in the rush hours. The majority of all of our agricultural and mineral productions are sold at the same price in the market whether they are sold in large or small quantities. Even with manufactured goods there is not so great a difference as some imagine. With regard to a service charge there is an argument often applied that seems to me not altogether sound.

It runs all through the decisions of the Wisconsin Public Service Commission. It is based on the theory that all the fixed charges do not vary with the output but can be equally divided among the consumers, with perhaps a little variation according to the size of the service pipe for the meter. Of course that is true for a day, or a week, or a month; it is not true for a decade at all.

The very essence of the meter system is in the reduction of the fixed charges; the very essence of the argument for the meter system is, that it does affect the capital, it does affect the investment. For every dollar you put into meters you save two or three dollars in capital, perhaps more, aside from any possible effect on the operating expense, aside from other arguments. A minimum charge, however, may be defended as tending to prevent prejudice against meters on the ground that with meters people will not use enough water for cleanliness.

It may be necessary for the sake of revenue to have a considerable service charge or a considerable minimum charge, and it is necessary in some cases to have a lower rate for uses beyond a certain amount; but I think you will find that it should be resorted to just as little as possible, that it is going to be more and more unpopular as it is understood; that the mass of our water consumers will resent the idea of the lower rate to the big industries. They have resented it in the railroads; they have resented it in governmental management; they are resenting it in water; they have not been used to it in gas nor in street railways, where the long haul is the same as the short one. They assent to it in electric light because of local conditions, because of the lack of storage facilities, because the great peak of the load that has to

be met in a certain way; but there is one point I want to emphasize, that I believe it is a dangerous weapon to fool with very much. Go a little slow about it. Weigh the situation pretty carefully; do not go any further in that direction than your financial necessities compel.

Mr. Watson: I would ask the gentleman who read the last paper to state whether the minimum readiness to serve charge was allowed to be utilized in the consumption of water charge; that is, if it is $5 a year, should the consumer have credit for that much water?

Mr. Leisen: The paper distinctly stated that the service charge did not carry with it any supply of water; it is a fixed charge for the installation or readiness to serve and the charge for water consumption whether it be 1000 gallons or 1,000,000 gallons, is an entirely independent charge. All consumers would be charged the same rate without reference to the service charge.

Mr. Watson: The reason I asked that question was, that we have been trying to arrive at a fair minimum charge of say 50 cents per month for a $\frac{5}{8}$-inch, $1.00 per month for $\frac{3}{4}$-inch, $1.50 for 1-inch, $2.00 for $1\frac{1}{2}$-inch, $3.00 for 2-inch, $4.00 for 3-inch, $8.50 for 4-inch and $10.00 for 6-inch. To overcome the point that has been brought out I think quite strongly in the discussion of this paper, that it would not be fair to charge the large consumer a reduced price below that charged the small consumer, some of our members may have adopted or used this kind of a bill, one that we have in use in our company: make all consumers pay 40 cents for the first 100 cubic feet; for the next 300 cubic feet 25 cents per cubic foot. That would make the first 400 cubic feet $1.15. The next 300 cubic feet at 20 cents; the next 500 cubic feet at 18 cents; the next 1300 cubic feet at 14 cents, and so on until we arrive at the next 67,000 cubic feet at 5 cents, making the total consumption 133,800 cubic feet, taking the total all the way down. Now if you divide the total amount charged by the total cubic feet we find the consumer is only paying 6 cents a 100 cubic feet although he paid for the first 100 cubic feet 40 cents. If he only uses 300 cubic feet he pays the same as the small consumer.

Mr. Chester: The paper that we have heard this morning it seems to me is going to be of great value to public service corporations and other like bodies that become endowed with absolute rate making powers regardless of political, commercial or other influences; but

to the small water works plant privately owned the application of the principles outlined this morning are practically impossible from a municipal relationship standpoint; and in most cases if applied would spell ruin. To put to you a concrete proposition of what I mean by "spelling ruin," let me give you figures as to one corporation in which I am interested. There is an investment of $180,000. Total collections annually are about $18,000 or 10 per cent. One corporation taking water from that Company pays to it a sum greater than the total net profits above interest and operating expenses. They are paying 5 cents per 1000 gallons. The territory supplied parallels a river for about four miles. The particular consumer mentioned at 5 cents per 1000 gallons in this case is a railroad whose line is between the river and the territory supplied. If we were to raise the rate above 5 cents that railroad would pump its own water, we would be deprived of that revenue, and would show red figures on the side where we now show black. We have a different way of looking at the reasons for a sliding scale or a low rate to the private consumer, and it is this: we believe that we should charge a private consumer about what it would cost him to pump his own supply. If we do not sell to him at that price we cannot expect his patronage. I might go on and cite numerous examples. There is another water company on another river where revenue from a corporation is paying a little more than the profits. The water company is only able to hold that corporation at $4\frac{1}{2}$ cents per 1000 gallons by virtue of an inter-ownership between the water company and the corporation; and if the latter saw fit to sever their connection for some reason or other that water company would be losing money. I cannot altogether agree with Professor Bemis' remarks on the idea that everything should be sold on the same basis for the long and short haul, for I know that when you send a carload of freight over a railroad you get a lower rate for a carload than for less than carload lots. I know that a wholesale grocer sells to the retail grocer at a great deal less than the retail grocer sells to the private consumer. Numerous examples such as this might be cited to contradict the proposition of selling large and small quantities for the same price. I believe thoroughly that when the time arrives that we can adjust everything regardless of political or social considerations we can fix some way that our water companies can become paying propositions and sell water in the manner outlined by the author of this paper, i.e., the same price to everybody, and let the proposed service charge make up the difference; but until we can get the rates made by public service corporations or people uninflu-

enced we cannot think of adopting such a plan. I can express the fear that this paper will only make trouble for the operator of the small water works by its being brought up by the politician as an argument to secure lower rates.

The matter of whether or not the water company or the municipality should furnish the meter is an interesting question. Where the water company must set, furnish and keep the meter in repair it certainly means a charge varying from $1.00 to $2.00 per annum in addition to the cost of service if the consumer furnishes and maintains the meter. But it is pretty hard to make the consumer see that that two dollars rental charge is a necessity.

In regard to the percentage of water passing through the meter which is not registered, I have never had an opportunity of going into that feature in a satisfactory manner; but I have had the opportunity a number of times of checking up certain plants where every consumer was metered; and I have yet to find the company supplying domestic consumption, taking the output measured in whatsoever way you will and comparing it with the total meter readings, that could account for better than 78 per cent of the water supplied. Where the other 22 per cent has gone in some way may be accounted for by pump slippage, leakage from the mains, under registration, and all of that; but that is as close as I have ever come in a company furnishing a municipality where there were a large number of small consumers.

The illustration by a comparison with the telephone service is a good one in a certain way as to the furnishing of water. One line leads into a house in which several families live, and a certain charge is made for the service, which I believe has been pronounced unjust here; but let us look at it in another way. Only last week on an inspection by the superintendent of one of the plants in which I am interested, we found four houses connected with one service, and four different families living in the houses, two houses in front and two on the alley. The houses in the rear had colored families living in them; nevertheless the four families were paying but one minimum through the man that owned the property. Is that just? It is much the same as the telephone case. He was notified that he would have to pay four minimums in the future.

The commercial fact that we have got to meet in the service along the Ohio River in the vicinity of Pittsburg is that we are compelled to charge about 5 cents or less to the manufacturers, because the manufacturer can pump his own water for that or less. Not three miles away from where we charge one corporation 5 cents a railroad

pays 10 cents per 1000 gallons because there is no stream near by except such as are so contaminated by mine water as to be useless, and the railroad can not get to any other water.

I believe that in placing the minimum rate at ten cents to manufacturers in cities like Louisville and New Orleans you are going to drive away the manufacturer that cannot locate along the river; and you are going to compel the manufacturer who is fortunately located along the river to pump his own water, for we know he can pump it for less than 10 cents per 1000 gallons.

MR. LEISEN: I mentioned no 10-cent rate at Louisville. I said we hoped to secure the manufacturers by reducing our 5 cent rate to 4 cents per 1000 gallons.

MR. WILLIAMS: Mr. President, I do not rise for the purpose of discussing Mr. Earl's valuable and interesting paper. To do this in the proper manner, and in accordance with its merits, one should have the paper before him to study and analyze; but there were a few salient points, particularly some touched upon by Professor Bemis, that are extremely important. The analogy drawn between the operation of water works, and the carrying on of other governmental functions, such as the post-office department, seems to me rather an unhappy one so far as the deductions sought to be drawn from it are concerned. The post-office department has an absolute monopoly in the way of carrying the mails, and is only subject to competition by express companies in handling light weight merchandise. Besides, the government does not charge the same price for carrying all kinds of mail matter. Letters are carried for two cents an ounce, while printed matter is handled for varying prices, ranging as low as 4 ounces for 1 cent, or one-eighth the rate for letters.

The theory on which flat meter rates are advocated for water works plants by Professor Bemis, applied to the mail service, would establish the same rates for printed matter and for letters.

But the main point that has not been mentioned is, that the post-office department has practically no plant, and hence no fixed charges to meet, operating expenses being all that must be considered. Though having a virtual monopoly of the business, there is no interest to pay on plant and buildings, and the cost of these never enters into postal rates.

Water works, on the other hand, must have a complete system, including buildings adequate to contain the machinery and equipment.

They must be ready at all times to furnish fire protection without notice, as well as to meet ordinary demands. There is then a certain upset revenue in each case, that must be provided, that bears no relation to the amount of water furnished. Besides, operating expenses are greater proportionally for small consumers than for large ones, and the value of the service varies in like proportion. Whether the community is served by a private company, or the municipality, the people must ultimately pay for the service, unless, as is sometimes the case, it is furnished by a company at a loss.

Such being the case, it is to the interest of every private consumer that the plant shall return as great a revenue as possible. Even if the service is rendered at reduced rates, so long as it shows a margin to the credit of operation, ignoring interest on capital, the private consumer profits. Hence discriminating rates may sometimes be desirable and profitable to the consumer discriminated against.

Neither a city nor a corporation serving a city, has a monopoly in the sense that every possible consumer must take water whether or no. Hence, the problem of possible competition from some of those who should be patrons must be met, and varying prices for water becomes a necessity, if cheap service is to be realized by those consumers who must use, or will use water whatever the price.

This point has been well covered by Mr. Chester, but I want to reinforce it.

Allow me to mention a case in point where a great number of railroad companies within the city limits, using a large amount of water, were being furnished by a water company. This water company has been operating for twenty-seven years or more, during all of which time it has been barely able to exist, not live. It kept out of the hands of a receiver, but it was done by reason of making a rate to the railroads, which, though a discriminating one, carried a profit in operation, and would prevent the roads serving themselves. The water company's income during the last year was $90,000 and of this $24,000 was contributed by the railroads. Without this business the company could not have continued to operate. The difference between the cost of pumping the water which was furnished to the railroads, and the price it got for it, was the margin that saved the company's life.

This plant has just passed into the hands of the city. If the board of aldermen conceive the idea that the railroads shall pay the same rates as the small private consumers, this business will be lost, and the city as a whole or the private consumer, will have to bear all the burden of operating the works.

Either as water consumers or tax payers, the people of the city must furnish the necessary revenue; the railroad companies will only help as long as they conceive it to be to their interest.

Mr. I. B. Brown: There is a great problem involved in this discussion. The ideal rate seems to permeate the paper which has been read by the gentleman from New Orleans, as also the one by the gentleman from Louisville—the ideal rate that is free from discrimination, that treats all on the same basis. I am not so sure after our enlightenment on that subject of the ideal rate whether it is entirely practicable. When the government of the United States undertook to regulate the transportation problem it never got away from the carload lot idea; and if it had, the courts would have reversed the government upon that subject, as it has been sanctioned in many decisions, where a certain rate is made applicable alone to carload lots.

I undertook to get the floor before the gentleman who last spoke, upon the very point that he discussed; that is, the transportation of the mails; because the government of the United States classifies the mails; they are carried at different rates, as he very well said. But it does carry letters from Washington to California, at the same rate that it does from Washington to New York. Now is not that a species of favoritism? Is not the government doing for California something better than it is doing for New York? Yet it seems to be on the face of it an ideal proposition. You will remember in the early discussions on the question of transportation that there were those who were so much in favor of the ideal that they said that the men who were producing coal and transporting it to different localities of the country, it must be so produced and so transported so that it shall cost the man in Omaha no more than it does the man who is located in localities much closer to the mines. And there were arguments that might be used in favor of such a proposition. The coal heap is a great factor in the manufacturing business, and it is said with some force that a man in the manufacturing business in Omaha or Spokane, or any place on the Pacific coast remote from the coal regions, in order that he might compete with other manufacturers of the country should have that great power factor of coal laid down in his yards at the same price per ton for transportation as the man near by. Now that is ideal; but it is not practical. So I claim that a municipality owning its plant, its water supplies, may perhaps approach a little nearer to the ideal than in the case where water is furnished by a private cor-

poration. In our company we have a minimum rate of $1.80 for three months for a private family. We make a charge to certain manufacturers of say $200 or $300, and yet the expense of administration is practically the same for the $1.80 consumer as it is for the $300 concern. There is your carload lot idea that has been sustained by the Supreme Court, which seems to furnish some justification for a lower rate per 1000 gallons for the larger consumer than for the smaller consumer. So there is a good deal yet in our benighted condition that makes the ideal rate somewhat impracticable. When you have a municipality and a people who are generally just but often misled, to deal with, you will find that the question of integrity is not always on one side. To illustrate, in our little town we had quite a copious spring that came from the hillside, which supplied two or three families with water; it was connected with one of the streets in the town by a pipe the size of which I do not remember; but in the slow processes of nature which sometimes dry up springs this spring ceased to flow very much to the merriment of the water company. But in a few years it was discovered that this spring was flowing again, and it seemed to flow more copiously than it had in past years. The water company was very much exercised about it. An investigation was made and it was found that one of our good citizens had connected the pipe that led from the spring with the mains of the water company. At first it seemed like that wonderful spring that came up in Andersonville from which the prisoners there, the victims of that great struggle, were supplied so copiously with refreshing water. It also seemed almost as miraculous as did the grateful flow of water when Moses struck the rock in the wilderness in the old biblical days; yet there was a question of integrity involved, and it was not against the water company either.

Whenever practicable we should approach the ideal, and when there is a departure from the ideal there should be facts to justify such departure and even when the action is absolutely right there will be criticism of a pronounced character. If we would conserve our own interests we will predicate every action on lines that will stand the test of fairness.

Mr. Hodgkins: One thought has come to me that has not been touched upon in this discussion, and that is, that we are trying to sell sugar and sand out of the same barrel. The manufacturer on the Ohio River may want clarified water but is not concerned as to whether it is pure or not. The manufacturer in Buffalo or Toronto is

perfectly content with water from the Bay; but the small consumer, in Toronto for example, requires that the water be taken at great depth beyond the island and filtered, and then conveyed in a tunnel across the bay. The character of the article demanded by the small domestic consumer is very different from that required by the large consumer and the cost is very much more. If any justification is required for the minimum charge you certainly have it without looking farther.

We need not be concerned about infringing any governmental principle on this question of the minimum charge for water. Should it come to pass by any possible means that one price per thousand gallons to all consumers, large and small, was compulsory, the result would be the dual system, one for potabel water, and one for manufacturing and fire protection; and I will venture to say, as I have said in the past, that in many cities the duplicate system will eventually be established.

MR. DUNHAM: Unless there is an error in the printed abstract of the papers before this Association it is affirmed that under the new rates the city of New Orleans makes it possible for one family to obtain water at a less rate than is charged another family living in a house precisely the same in size and under identical conditions. If this be the fact no time should be lost in changing the said schedule and regulations so that all consumers shall receive uniform treatment. It must not be forgotten that the city is now the source of power and authority. There is one purveyor of water. The primary element of fairness demands similar treatment for all similar cases. Each applicant should be duly registered by the purveyor and to him should be extended the same rights and privileges that consumers under similar conditions enjoy.

To sell water at one price regardless of the use to be made of it insures the worst kind of inequity. Apply this faulty method to fire protection for a large manufacturer. The city of New Orleans might as well levy a tax upon all citizens to pay that manufacturer's insurance premiums. The water used to extinguish a fire is worth to the owner of the premises vastly more than the meter rate charge. The protection offered is of great value when no water whatever is used. For these advantages he should pay. It is the same with a family. The service price has been fixed—let us say fairly. If now you set up conditions under which a like family is obliged to pay more or less for the same service, you introduce injustice and injustice always

brings trouble. To say purveyor No 1, the city, sells water to all at the same price charged purveyor No 2 is in no wise a proper defense. Purveyor No. 2 was the creation of purveyor No. 1 and in this as in all other known creation cases his acts are the acts of the original or first purveyor. The responsibility rests with the city. The fault lies with the schedule or regulations under which it is possible for the city through an agent to practice unfairness. It may not be appreciated at first. It will become evident in a short time. If the city wishes to give water to poor or impoverished residents no objection should be urged by an outsider, but that kindness would hardly pertain to the discussion of a rate schedule.

The schedule as printed lacks definiteness. "Serving not over two persons and rooms" may mean one person in one room or two rooms or two persons in one room or two rooms.

Mr. Sherman: Our company was one of the first to use meters on water supplies. Many of those meters have been undisturbed from the day of their installation until the present time. We have taken out in the last two years about 5000 meters, which is about half of the total number of meters we have. Some of them have been in use longer than twenty-two years. I believe four different types have been in from ten to fifteen years, and we find no such average as has been intimated of under-registration of 20 per cent. We do find differences between the various makes of meters quite naturally; but we find that many makes on the full stream register absolutely accurately, and that the great majority of them register within a very few per cent of 100. As for the more recent installations, even under very hard service we find that if they vary 3 per cent they are varying more than the average.

We used to have the old split rate system, which we changed two years ago to a sliding scale, to my mind in many ways eminently fair; and for that reason, while I presume there was no intention of casting any reflections upon the sliding scale, I would like just to say that the rebate has not anything to do with the sliding scale. The essence of the rebate, as I understand it, was that it was secret and was given a favored few. The sliding scale applies to all under the same conditions of consumption. The man that takes 100,000 gallons gets exactly the same as another man who gets 100,000. The man who gets 50 gallons gets the same rate as any other man that gets 50 gallons; so all along the line. Under the public service decisions in this state, as I understand it, that classification is entirely

proper, it being understood that all within each class are treated alike. Personally I can see that it is entirely proper to say that a man who uses 100,000 gallons under one condition shall pay a different price from the man who uses 100,000 gallons under different conditions. We have not done this because of the fear of complications and the charge being made of discrimination; but there are conditions whereby the making a lower rate than on the whole would be profitable to us at the present time, would get us additional business that is now being supplied through filters from the river or through filters from the canal; and I think it is entirely proper to consider getting this business. Certainly with gravity systems when extensions are made there may be over-development and there must be surplus water; and it goes without saying that it is more economical to sell that surplus water for what you can get for it than to let the water go to waste.

MR. TRAUTWINE: Mr. Earl, while apparently favoring the general use of water meters, mentioned a class of cases where considerable under-registry might occur. Mr. Earl's figures were challenged by Professor Bemis; but, granting their correctness, I submit that careful concern about under-registry (while quite in order with a water company, whose revenue depends upon a careful counting of the pennies), is out of order in a municipal supply, and indicates a failure to recognize what seems to me to be the chief function of a water meter, namely: that of a scare-crow.

The water meter makes every consumer an inspector; so that, in a majority of cases, this supposed unmeasured waste would never take place.

In behalf of justice, Mr. Leisen advocates the abolition of the minimum meter rate, urging that each consumer should pay for exactly what he uses; but I submit that we may pay too dearly for an ideal "justice."

On our trolley cars, we commonly pay a nickel, whether we ride two blocks or two miles. It would be more nearly just if we paid so much for each block traveled, but the gain, in justice, would hardly warrant the cost, in inconvenience.

The millionaire president of a water company, who pays large taxes on his park and palace, spends most of his time in Europe, and scarcely uses our streets at all, whereas the underpaid municipal water works superintendent, who owns no property and pays taxes only through his board-bill and his purchases of the necessaries of life, may use the

streets from morning until night. To overcome this injustice, each pedestrian might be furnished with a strip of coupons, and a policeman might be stationed at each corner to punch each strip as its owner completed a block; but the practical man will easily discover objections to such an arrangement.

Another interesting case, bearing upon this question, and prominently brought out during the discussion, is that of the postoffice.

Professor Bemis (arguing against lower rates to large consumers) mentioned that the cost of a 2-cent postage-stamp is 2 cents, whether the purchaser buy one stamp or a thousand stamps; and Mr. Brown remarked that the same 2-cent stamp, which carries my letter across the street, would carry it to California or to England.

These facts strikingly bring out the contrast between state and corporate management. The corporation is left to get its compensation out of the public in the shape of profits, real or fictitious. Hence its first object is recompense. The state seeks only the benefit of its members. Hence its first object is service.

If the postal service were conducted by rival corporations, we should have differential rates, based upon mileage and upon difficulties of transit. The state, at some sacrifice of "justice," makes one rate for the entire country; and the resulting gain, in the matter of convenience, is so enormous that the trifling injustice is forgotten.

Mr. Williams (endeavoring to show that the postoffice does discriminate in favor of the large customer) argues that the postoffice, while charging 2 cents per ounce on *letters*, carries *periodicals* at 1 cent per pound; but this fact merely emphasizes again the difference between state operation, conducted for service, and corporate operation, conducted for profit.

The government, upon the ground (I believe) that periodical literature is a most efficient instrument in the diffusion of useful knowledge, gives it a nominal rate, probably carrying such matter at a pecuniary loss, and taking its pay in the supposed mental and moral up-building of the people. The private corporation has no interest in the mental and moral up-building of its customers. It knows only dollars.

On nearly the same principle, some municipalities (Philadelphia, for instance) give free water for fire protection, recognizing that the trifling cost of the water consumed, at even a great conflagration, is infinitely repaid, to the community, by the added security against fire.

Moreover, within each of the two divisions mentioned by Mr. Williams, the government's rates are independent of the volume of busi-

ness. The American Water Works Association pays only the same rate, 1 cent per pound, upon its *Proceedings* as does the enormously greater business of the *Ladies' Home Journal;* and the poor man, who writes, once a year, to his brother in California, pays the same rate, per ounce, as does the Unites States Steel Corporation.

Mr. Sherman protested against Mr. Earl's placing of differential water rates in the same class with rebates, by railroads, to favored shippers, and held that the only proper objection against the railroad rebate is its secrecy, and its use as a species of favoritism, and that it is legitimate for a water company to discriminate, in rates, in favor of large consumers, provided the rates are published and adhered to.

This, while doubtless true, from the proper standpoint of a business corporation, raises an interesting question. If, as we are told, competition ought by all means to be encouraged, in the public interest, should not a municipality give the lower rates to the *smaller* consumers, that competition might be encouraged to the utmost?

It has been said that, with the municipal, as with the corporate, water supply, the main question, after all, is dollars. But this is not true. The municipality's interest in dollars is insignificant in comparison with its interest in the physical, mental and moral welfare of its people.

A city builds streets and parks, at great expense, and is repaid a thousandfold, though it gets no dollar of revenue directly from either. Without attempting any calculation, I venture to say that the city of Rochester could not afford to close all her streets for a month, even if offered ten times all the money those streets have cost her.

Similarly, a public water supply is worth, to a city, infinitely more than the sums spent in its construction and operation, and the benefit derived from it is not to be measured in terms of the dollars paid by its water-takers. Hence, where a municipality cannot build its own works, a water company is a public benefactor, and is justly entitled to compensation far above what it can expect from the rates. It should, therefore, as a contractor, deliver the water, at a handsome profit, to the municipality, to be dealt out to the citizens upon the municipality's own terms.

Otherwise, the private water company, like every other private business enterprise, is an impertinence, a relic of barbarism, still tolerated only because we cannot become civilized all at once.

This fact is witnessed by the hard-luck stories of suffering water companies, with which our convention sessions resound, culminating in Mr. Chester's beautiful swan-song, delivered this morning. All

foreshadow the inevitable doom of the curiously old-fashioned and obsolescent method, under which this matter of vital public interest is still entrusted, here and there, to private hands.

Mr. Hering: (By letter.) Mr. Earl's paper on "Water Rates" is in my opinion one of the best contributions we have on the subject. Throughout the same we find not only a sincere and impartial endeavor to reach a fair basis on which to proportion the cost of a water supply, but we find also an intelligent discussion of the whole subject based upon the actual experience of a large city. The conclusions therefore, naturally have weight and demand attention.

Mr. Earl very properly does not put himself in the position of a partisan, either for the public or for the private consumers, or for any private corporation which is in business for the purpose of making a legitimate profit on its investment of both money and brains. He endeavors to treat the question broadly and impersonally, so as to arrive at equitable results which will be just and fair alike to all parties. He proceeds logically, first, by making an analysis, weighing each part, and then, by making a synthesis, recombining the parts in a practical way to effect a rational division of the cost.

Flat rates are unfair, wasteful and unjust. In short, they are as inequitable for the distribution of water as they would be for distributing other commodities, such as gas, electricity, steam, milk and food. They place a premium upon waste, not upon economy. The wasted part of the commodity must be paid for by the careful and economical user, who is thereby actually fined for practicing one of the best qualities of a citizen living in a progressing community.

Flat rates have been on the other hand, apparently justified and are almost exclusively used in America for city transportation. Carfares are generally placed at 5 cents a ride, whether it is one block or fifty blocks. This custom has been largely a matter of convenience and simplicity, not of justice. The excessive fare for a short ride pays the insufficient fare for the long ride.

That this flat rate for carfare will be eventually abolished, is my firm belief. It has already been done in Europe, where people cannot afford to waste in the same manner we do in our country. The fare is adjusted somewhat to the distance traveled. Where one pays his fare at the station, as on their rapid transit lines, the ticket is punched when passing the entrance gate. In addition to this practice, the European ticket is not collected until the passenger passes the exit gate. By the color or other sign, the collector quickly recognizes

whether the passenger has paid the proper fare to the station where he has left the train. If he has gone beyond the point to which he is entitled to ride, he must stand aside until the crowd has passed and pay the difference which generally includes a fine. Where one pays on trolleys, a slip of paper is given for the distance desired. Collectors or controllers enter the cars, check the slips and gather in the fines for over rides. Some lines in America have already similar practices, excepting the exaction of fines.

With this arrangement, one can ride in England, France, Germany, etc., for 1 cent. or 1.4 cent. a distance for which many Americans would hesitate to pay 5 cents, and therefore, prefer to walk, while the European corporation is apt to get a fare and on the whole to take in more money. Also in other respects the trolley services are generally superior. The flat rate idea will never again be countenanced in Europe even for carfares, as present practices are quite satisfactory.

Another injustice resulting from the adoption of the flat rate, is seen when one asks the owner of a large property to pay a less tax per unit than the owner of a small property for the same unit, other conditions being equal. The tendency towards "wholesale rates" in this as in other municipal assessments is found in practice to virtually increase the taxes of the poor and to decrease the taxes of the rich.

The flat rate idea or an average figure, can be partly extended only to such parts and to such a degree where it becomes impracticable or unfair to make a close discrimination. Mr. Earl applies an average figure to that part of the works which includes the making of connections with a house, the reading of the meters and the keeping of accounts. For this service a flat rate charge, equal to the general average cost, is quite fair, because it is impossible to get exact figures for each case and if it were possible, it would be exceedingly difficult to determine and moreover unfair to the property owner, because he is not responsible for certain conditions which control the cost, such as the location of the main on one side of the street, the easy or difficult character of the excavation, etc.

For the above reasons, Mr. Earl advocates paying for water in general by measurement, a practice which is growing in our country and is now almost exclusively the custom in Europe, and to which there seems to be not the slightest objection when viewing the alternative conditions. In New Orleans the board has determined to meter the water for all users even for non-paying consumers. It has therefore taken the extreme position.

Mr. Earl properly calls attention to the fact that a public water

supply must be a coöperative system between the municipality and the private individuals. The former uses water for public buildings, for institutions, for fire extinguishing, street flushing, and sprinkling, and for sewer flushing; the latter for individual purposes. This brings a clear distinction between the position of the tax-payer, who pays for the general city maintenance, and the rate-payer, who pays for his private use of water, which discrimination should be more clearly understood and made than is usual. Mr. Earl makes this point very clear and it is hard to see how it can be easily set aside.

As meters are placed on all services, public and private, Mr. Earl proceeds to find the proper division that should be made, to determine the payments by the public and those by the individual. He suggests logically that the tax fund should contain an appropriation for public water, which is to be paid for according to the amount consumed for public purposes. This practice is also found in Europe and is as practicable as it is equitable.

The water rate per unit must be carefully and justly determined. It should be sufficient, whether the works are owned by the city or by a private company, to pay a fair interest or profit on all capital judiciously invested, from the time of the inception of the enterprise to the time when water is delivered to consumers, including all legitimate expenses, even for preliminary investigations, surveys, studies, and legal expenses clearly incurred for the proposed work. The rate should be sufficient to pay for all of the operating expenses and also for a depreciation fund, which is sufficient to maintain all of the works perpetually in a first class condition.

Whether or not the rates should include also the creation of a sinking fund, which gradually removes the bonded indebtedness and, after a certain number of years, leaves the works a free and paid-for asset to the city, or the company owning the works, is a matter distinct from engineering considerations.

As usual an equitable division of cost will tend to benefit chiefly the small consumers, as Mr. Earl indicates.

Mr. Earl assumes that the under-registration of meters may on the average be estimated at 20 per cent. It has always been somewhat of a puzzle to account for all of the water pumped into a distribution system. A large proportion has therefore been usually set down as "unaccountable," "needless," "curable." Some of us have suspected that the unaccountability might lie in a too strict adherence to the meter figures, as representing the amount of water to be accredited to the metered supply. This suspicion is growing and Mr. Earl's

assumption of an average of 20 per cent deficiency does not appear to me at all improbable. This fact of course, in no way undervalues the meter system.

Mr. Earl: In the discussion upon the writer's paper, the assumption of 20 per cent under-registration in meters has naturally been questioned. This assumption was made more to bring out data in this connection than with a serious belief in its correctness. It *is* seriously submitted, however, that the actual use of water for an average family will hardly exceed 200 gallons per day; that a $\frac{5}{8}$-inch meter will in most cases fail to register at all on a constant waste of 2 gallons an hour, which is 48 gallons in twenty-four hours, and is quite likely to fail to register on wastes even up to 5 gallons an hour, which would amount to 120 gallons in twenty-four hours. These wastes, if unrecorded, would amount to 24 per cent and 60 per cent, respectively, of the recorded consumption. The only question, therefore, is what is the average leakage per house which escapes at a rate below that at which the meter will register? With faucets not always tightly closed, and often slightly out of repair; with occasional small leaks in the pipe system, some of them under ground; and with the known tendency of water closet flush tanks to develop constant wastes through both ball cock and discharging apparatus, may it not easily be that this question is more serious than it would at first seem, and that even with an all meter system the water works has a larger interest in the character and condition of the consumer's internal plumbing arrangement than is now being displayed and that much lost water in all meter systems which is now charged to distribution system leaks is in reality meter under-registration? Many types of large meters, if most of the time working on small rates of discharge and only occasionally called upon for large flows, are susceptible of even worse under-registration.

The principal argument advanced against the method of rate making suggested is the statement that sometimes a plant can be made to pay by selling a quantity of water to large consumers at a very low price, which large consumers could get their supply elsewhere at a low cost and would do so except they be given such exceptionally low rate.

It is true that in the case of a system which is overbuilt for the present natural demand upon it, any increase of consumption will decrease the total operating and fixed charges per unit of output, and anything that will increase legitimate consumption at rates at all in

excess of the actual cost of putting this additional amount of water into the mains would tend by this much to increase the surplus of revenue above operating expenses. New Orleans, for instance, can put out additional water at an additional cost for pumping and purification of less than 1 cent per 1000 gallons, and, hence, if she could acquire several large consumers at 2 cents a thousand gallons, who would use 10,000,000 gallons of water per day, she would show an increased net revenue of over $40,000 per year by so doing.

A study made a year ago showed that about 8 per cent of the New Orleans consumers were then using 66 per cent of the paid supply, and paying 41 per cent of the revenue. These large consumers are paying 10 cents per 1000 gallons and would naturally object to any lowering of rates to new large consumers which did not include them also, and to include them would change the net gain above indicated to a net loss very much greater.

If lowering rates for water will increase consumption, as it naturally will, why is it not the best policy to make the "lowest price at which water can possibly be sold" to everybody, and thus encourage the most liberal use, which its natural price justifies, over the widest possible field?

For a water works system there is a certain cost per unit of capacity, and when the capacity is exceeded the system must be enlarged. The sale of any portion of the output at any time at a price less than would be necessary (if the plant were operated to its full capacity) to charge for all water sold to pay interest, depreciation and maintenance and operating costs (plus a fair profit for a privately owned plant), means the establishment of a price that can only be *maintained* at a loss, since the capacity so utilized could be more profitably utilized, as consumption increases, by the sale of this same water to consumers who do pay an equitable price; and the investment in extensions to take care of unprofitable consumers would not be necessary. One trouble is that we have all designed plants on data derived from the consumption under flat rate cities, and when we get down to a meter basis we find our estimates of consumption far too high. This has its compensating advantage in giving a good margin of capacity in the fire service; and we shall probably have to recast our ideas of the fair proportion of revenue which such fire service should pay. The able and exhaustive paper by Messrs. Metcalf, Kuichling and Hawley gives a splendid basis upon which to determine the cost and value of fire protection, and therefore the extent of payment for same which is warranted for any given character of such protec-

tion. Where the information made available and the principles outlined in this paper on fire supply and the principles suggested in the writer's paper are jointly and correctly applied, the writer believes that a rate making study for any given city will produce the nearest to a universally equitable water rate that can be made.

The idea that large consumers will not pay the rate necessary if they can reach an independent supply has not been found true at New Orleans. The Mississippi River skirts the city for 16 miles, and many of the largest consumers are located along the river front. The Southern Pacific Railroad and Steamship Company abandoned a pumping plant and filter equipment of their own to become a very large consumer of 10 cent water. The city is not attempting to compete with raw river water, or with artesian wells, and offers no objection to the use of these by any one for any purpose for which they are fit.

If in order to encourage manufacturing it is necessary or wise to make a very low water rate, it is doubtful whether it would not be the tax-payers of the city rather than the water rate-payers who should foot the bill. With the writer's rate scheme such a low rate for any given class of consumer could be made and its cost assessed against either the tax-payer or the rate-payer, or both, and openly so assessed.

Some cities favor manufacturers by exempting them from taxation, which amounts to an open assessment of their taxes against all other tax-payers. These are questions of public policy which should be decided on their merit for each city, and no matter how decided could be worked out in the writer's rate scheme without conflict with the principles therein suggested.

The writer cannot possibly reconcile the attitude of those sliding scale meter rate advocates who in order to *create* a large consumption induce certain large consumers to take water, say at 5 cents per 1000 gallons, and then after setting a minimum quantity and rate for small consumers (which they will admit yield a satisfactory profit) in order to *discourage* consumption threatens such small consumers that if they use or waste water in excess of the stated minimum amount they must pay 25 cents per 1000 gallons for it up to a quantity that is far beyond their probable limit of consumption. If increased water consumption at the minimum price is desirable and profitable, why not follow the Louisville plan and adopt a "ready to serve charge" that varies with anything from the size of meter and connection and includes an item that is supposed to contain some portion of the general cost, as in Louisville, to the amount the service

will bear as measured by the relative pull of various classes of consumers, or of individual consumers, as is indicated to be the frequent practice, and then set "the lowest possible price at which water can be sold" for *all water*, thereby obtaining the maximum possible efficiency of all of the consumers in increasing water consumption?

This Louisville plan, next to the flat rate plan, should have a maximum efficiency in increasing water consumption, but if the price for water is set at about the point which it would reach under the writer's plan, when the water consumption has reached the salable capacity of the plant it will not unduly increase such consumption. Applied with good judgment, this Louisville expedient would probably approximate a fair system of rates; it would not, however, in the writer's judgment, meet the test which he has stated in the italicized paragraph in the latter portion of his paper.

Practically speaking, a water works system from its source of supply to the myriad points where the water can be drawn from its mains has but one function—an ability to deliver water under adequate pressure. Its capacity to do this is limited, and a very large reservation of capacity like city fire protection should pay its full pro rata of all capacity costs. This being deducted, all ordinary consumers of water consume per unit of water drawn an equal proportion of every remaining cost entering into the creation and maintenance of the service. Why not then recognize this fact and adopt this for your water rate, adding to it, first, those additional items which are performed individually for each consumer in order to bring this water from the main in the street to his property line, to keep the account of the water used by him and collect its cost; and, secondly, a fair profit above cost for all of these items of service rendered?

If pull and influence must obtain a special advantage for some particular class of consumers; if somebody must be fooled, or if the system is going to be forced to reach results which it does not justify in any direction, then avoid the plan suggested.

The New Orleans law does not permit the making of water rates at all in accordance with the method herein advocated, although it happens that the figures assumed have fairly well justified the New Orleans rates as they stand. It is quite likely that other cities face conditions of law and APPARENT public sentiment equally or even more difficult. Laws, however, can be changed, and *general* public sentiment is rapidly molding in a direction that will assist in carrying out such rate revisions in public service corporations as will eliminate injustice and incongruity wherever found.

STEEL VS. CAST IRON PIPE

By Allen Hazen

That which follows relates only to large mains, which I shall define provisionally as mains 36 inches in diameter and larger. In the early developments of the water works business there was but little use for such pipes. So far as they were used, cast iron was the material employed.

Penstocks for water power were among the most frequent examples of large pipe lines at an early date, and for these riveted wrought iron protected by paint, red lead, or other coatings early came into use; the same material was used in water works service occasionally, sometimes because it could be obtained cheaply; at other times because a reliable material was wanted for difficult service.

About twenty years ago steel plates became available in large sizes and at comparatively low prices, and these at once largely replaced wrought iron for such pipes. Pipes made from steel plates had advantages and soon found extended application in the construction of the large water mains that were then demanded in increasing numbers to meet the needs of growing populations and the increased per capita use of water.

From that time to the present the relative merits of cast iron and steel for large water pipes have been discussed. Much has been said upon both sides. The author will not attempt to enumerate all the arguments that have been used, but only to present the salient features of the case as they present themselves to him, under the conditions that now exist in the northeastern states.

Steel costs more per pound than cast iron, but it is stronger and in some respects more reliable. A steel pipe a quarter of an inch thick may be, and often is, stronger than a cast-iron pipe an inch thick, and is commonly cheaper. When steel has replaced cast iron in pipe it has simply done what steel has done in a hundred other directions, in buildings, in machinery, and wherever a higher form of metal has advantages more than commensurate with its increased cost.

In the past a comparison of the two materials for large pipe lines has often rested upon a consideration of the relative durabilities, real

or supposed, taken in connection with the relative costs. The steel pipe has been assumed to be less durable, because the metal was thinner and would rust through quicker. But it was much cheaper. For instance at Springfield for twelve miles of 42-inch pipe for which competitive bids for steel and cast-iron pipe were obtained in 1908 the relative costs were in the ratio of 2 for steel to 3 for cast iron. Cast iron would have cost $600,000. It was actually laid in steel at a cost of $400,000. This ratio probably is not far out for the approximate relative costs of the two materials for large pipes under considerable pressures under the conditions that have ruled in the last few years.

The matter has frequently been presented in this way: the money saved by using steel pipe in a certain case, amounting let us say to one-third of what would be the cost of a cast-iron pipe line, or 50 per cent of the cost of the steel pipe line, if put at interest at prevailing rates would amount to enough to lay a new line of steel pipe at the expiration of some arbitrary period for which it is assumed that the steel pipe will last. The period assumed in making this calculation has seldom been less than twenty-five years or more more than forty years. In many cases this calculation has been made and the steel pipe has been put in with the belief that it was better business to use it even though it rusted through and ceased to be serviceable at the end of the relatively short period assumed for its life.

Large pipes, as defined in this paper, are most frequently used in the supply pipes of a water works system, and less frequently in the distribution, and in such supply mains other conditions than the wearing out or loss of strength of the metal commonly limit the useful life of the pipe.

With both cast-iron and steel pipes there is a continuous decrease in carrying capacity occasioned by the roughening of the interior surface principally due to tuberculation. This roughening is not associated with any appreciable reduction in strength, but it does practically reduce the amount of water that can be carried. On the other hand the amount of water that has to be carried normally increases steadily with increasing population. Reduction in pipe capacity and increase in demand limit the time that a given pipe will by itself perform the functions for which it was laid, and when, because of these, it ceases to be able to perform its work another line must be laid to help it out. When this occurs the first line may be considered to have lost a part of its value, and it may then be worth

only the difference between what it would cost to lay a new main to supply the whole service and to lay a new main to supply the service in connection with it. This will commonly be only a fraction of first cost. Much of the value is then gone although the pipe may be physically sound.

These practical considerations in most cases limit the full useful life of steel and cast-iron pipe in supply mains of growing cities to periods below the term during which the shell is sound.

The oldest steel pipe lines now in use are about twenty years old. They are still in good condition. Little has been spent upon them for repairs, and there is every prospect that they will continue in useful service for a long time. Curiously it is some of the more recently laid lines that have given most trouble from deterioration.

The weakness of a well made steel pipe is its liability to perforation. The experience of the last years has emphasized this, and recognition of a weakness is the first step in correcting it.

Perforations of steel pipe are caused in two ways:

1. *Mechanically.*—The escape of a small quantity of water through an accidental opening (at a high velocity because the pressure in the pipe is great) results in eddy action on the outside of the pipe which gathers grains of sand and brings them forcibly against the outside of the pipe, and in a comparatively short time cuts the steel and makes a perforation of sufficient size to be an important leak. The process of perforating a steel pipe in this manner is a rapid one after it starts. If the pipe is left with considerable leaks then enlargements may be expected to occur in short order.

The remedy is to test the pipe under more than full pressure before the trench is backfilled, to caulk it tight and to make the joints so substantial that there will not be chance for openings to occur. This may be done by careful workmanship and good inspection; it has been done with most of the lines of steel pipe that have been laid. Failure to do it in some cases has brought its own lesson promptly. Looking at the matter broadly there is comparatively little trouble in preventing such mechanical perforations, and little trouble is to be expected from them as the years go by.

2. *Chemically.*—It is a curious property of steel plates that corrosion is not equally distributed, but is concentrated in small places. Once in a while there is a place which for some reason corrodes more rapidly than the rest of the plate, and where finally the steel will be eaten entirely through, making an opening which allows the escape of water. There is clearly some imperfection in the steel

plate which allows the corrosion to take place which finally results in perforation, while 99 per cent of the surface of the plate remains entirely free from deep corrosion.

The matter is not an easy one to investigate, because when the perforation becomes apparent, whatever there may have been in the original plate to start the corrosion has been entirely eaten out and it therefore cannot be found.

Pittings and perforations have developed most extensively in some lines of steel pipe that were not among the first to be laid. In one case salt water from the ocean was a contributing cause.

Different pieces of iron and steel behave differently in sea water, but in general they corrode rapidly, and we may well hesitate to use steel pipe where it will be exposed to the action of sea water, or other highly mineralized water. If it must be so used the greatest care may well be taken to protect the pipe from contact with the water.

The writer believes that in many cases there is a reason for preferring steel to cast iron which is more important than the saving in cost, namely, the greater strength and reliability of steel. This greater reliability is due largely to the fact that steel is malleable, and therefore capable of being bent and deformed by settlement in the trench and movements under external forces without breaking or reduction in strength, whereas corresponding forces acting upon cast-iron pipe would break it.

Cast-iron pipe in the past has been commonly designed with a thickness of wall sufficient to resist, at an assumed tensile strength, and with an assumed factor of safety, the internal pressure of the water in the pipe, with a further allowance for water ram and generally with a further arbitrary addition to the thickness of the walls to cover inequalities in casting.

The actual test and proof of the formulas that have been used in making this calculation is that the pipe designed by them has in general been satisfactory in service, and the percentage of breakage in actual use has been small.

It is to be noted, however, that most of the experience relied upon in reaching this conclusion relates to pipes smaller than 36 inches in diameter. That relating to large cast-iron pipes, although considerable, is by no means as great.

It now seems that the forces taken into account in the formula are not the only ones that tend to break and that do break cast-iron pipe. In addition there are internal stresses due to the unequal cooling of

the casting; there are stresses that grow out of the fact that the pipe is unequally supported along its length and acts as a beam between points of support, and especially there is the weight of the backfill in the trench carried on top of the pipe and transmitted through the sides of the pipe to the material underneath. The tendency of this load is to break the pipe.

Professor Talbot of the University of Illinois has investigated the amount of stress produced by fill on pipes of cast iron and other materials by embedding them in sand and loading them to the point of destruction, and has recorded amounts of load or fill required to break them under various conditions.

The important matter for us is that the stresses that result from these other forces are cumulative to a considerable extent with those resulting from the internal pressure of the water in the pipe.

In a paper recently presented to the New England Water Works Association I attempted to analyze some of these stresses. I will not repeat at this time what is there printed; it will suffice to say that the stresses resulting from the load of backfill are important in pipes of large sizes and make a difference in the thickness of walls required. In other words, large cast-iron pipe designed by the formulas that have been used are not as strong in proportion as small pipe designed by the same formula.

Practical experience seems to bear this out, for there have been relatively more breaks in large cast-iron water pipes than in small ones. Statistics are not easily obtained of sufficient completeness to be of value, but I think almost any water works superintendent who has had 48-inch or 60-inch cast-iron pipe in his system, or even 42-inch pipe, will support the proposition that the destructive breakage of such pipe has been greater proportionally than with small pipe.

Further, the possibilities of damage with breaks in the large pipes are greater. It is possible in a few minutes to do thousands of dollars worth of damage by one break in a large pipe in a populous district.

The advantage of steel lies largely in the fact that the walls are malleable; the pipe may be deformed by the weight of the material placed upon it, by inequalities in the trench, and by other forces, and the pipe still retain its strength. Although steel pipes have been designed with nominal factors of safety no greater than those used for cast-iron pipe, when all the conditions are taken into account the actual factors of safety have been greater. With hundreds of

miles of steel pipe in service in the last twenty years, nearly all of it in large sizes, there have been but few recorded breaks, and, so faras the author knows, not a single case of a break of a destructive character; no such record can be shown for cast-iron pipe.

With cast-iron pipe, in case of breakage the side of a pipe blows out, and all the water that the pipe is capable of carrying is discharged until the reservoir is exhausted or the supply shut off. On the other hand, the few breaks that have occurred with steel pipe have resulted in comparatively small openings which allowed the escape of some water, but not by any means the full discharging capacity of the pipe. In two cases the pipe has broken squarely off, leaving a circular opening all the way around through which water passed. The ends of the pipe, however, remained intact and nearly in position, and the openings were of limited size and the pipes continued in service until arrangements could be made for repairing them by sleeves.

In another case there was one defective joint that broke under the test pressure that was applied before the pipe was put in service, tearing out and leaving an opening of some size, but this was repaired before the pipe was put in service.

The perforations of steel pipe that have sometimes occurred and that have been much talked about in the last years, resulting from the rusting or other corrosion of the metal and going entirely through the plate in some cases, result in a relatively small leak which does not interfere with the continued operation of the pipe, and which leak can be easily, completely and permanently repaired without shutting the water off.

It is to be noted that such breaks as have occurred in steel pipes most frequently during laying or preliminary testing, and less frequently in lines in actual service, have occurred, as far as the author knows, always where plates or lock bars or some other part was of steel that was relatively hard. The mild steel is the most malleable, and although it has the lowest tensile strength it makes the most reliable pipe. If there is breakage or trouble look out for hard steel that has escaped the inspector, or that was near the upper limit of tensile strength allowed under the specifications. For the greatest safety use soft steel.

Steel pipe is made at the present time in two principal patterns, namely, with double riveted joints and with lock bar joints. The lock bar pipe is believed to be fully equivalent in smoothness to cast-iron pipe, and will carry the same amount of water as cast-iron

pipe of the same size. Double riveted pipe, on the other hand, on account of the projecting rivet heads and the other irregularities of joints, has a greater frictional resistance. To obtain the same carrying capacity double riveted pipe should be 4 per cent greater in diameter than either the lock bar or cast iron pipe.

The circular joints of both double riveted and lock bar pipe are commonly made in this country by riveting. This makes what is known as continuous riveted pipe. With change in temperature the pipe tends to expand or contract, but is held by the earth and prevented from doing so, and the tendency is converted into stresses which tend to stretch or compress the steel, but which with good design never reach objectionable proportions. As these stresses are in all cases at right angles to those resulting from the pressure of water in the pipe their existence does not affect the strength of the pipe directly, although they may tend to bring out any weak points, and accumulating with other stresses they may have been factors in the production of such few breaks as have been noted with steel pipe.

These temperature stresses must be frankly recognized and provided for at every point. Overlooking them may mean disaster. The details of the joints and connections also must be very carefully studied and must be good.

The design of steel pipe has not been standardized in the same way that cast-iron pipe has been standardized. More skill is required to reach a good and safe design with it. Fortunately the early lines of steel pipe were designed by able men and the precedents then established were good. It is for us to see that they are maintained, and that necessary precautions are not omitted.

Pipe 30 inches in diameter can be successfully riveted in the field, although the space inside is rather small for good workmanship; 36-inch pipe is more easily riveted, and this marks the ordinary minimum limit of steel pipe as now made.

At Springfield, for the river crossing, two lines of 30-inch steel pipe were used. Steel pipe was selected in this case, not because it was cheaper, but because it was believed to be stronger and more reliable for an especially difficult service.

Generally speaking, with increasing size, cast-iron pipe increases in cost more rapidly than steel pipe. The saving to be made by using steel pipe as compared with cast iron is relatively small for 36-inch pipe, and would probably disappear with 30-inch pipe under present conditions, increases rapidly for 48-inch and larger pipe. This is true even with the methods of calculating the thickness of

wall of cast-iron pipe that have been used in the past. When Professor Talbot's work is taken into account, and the increased thickness logically called for is allowed on the larger sizes of cast-iron pipe, the difference will become greater.

There is a limit to the thickness of castings that can be advantageously used. A large pipe with very thick walls is probably relatively less strong and reliable than one with thinner walls because the internal stresses in the thick casting are greater and there is more likelihood of its going to pieces from its own internal stresses, acting either by themselves or in conjunction with other stresses from external sources that may come upon the pipe.

When all these matters are taken into account large cast-iron pipe for considerable pressures will increase in cost almost as rapidly as the square of the diameter of the pipe. In other words, there will be relatively small saving by using very large lines of cast-iron pipe as compared with several lines of smaller diameter.

In our practice in the last years we have seldom considered the use of cast-iron pipe more than 36 inches, or at most 42 inches, in diameter. In nearly all cases we have felt that it was better business to use steel pipe where most capacity was required, or otherwise to divide the line.

Sometimes we have surrounded steel pipe with concrete, thereby adding to its stability and durability. The cost has been increased, but not so as to equal that of cast-iron pipe.

DISCUSSION

Mr. Nicholas S. Hill, Jr.: (By letter) As in most other cases where a choice of materials or devices is available, we find advocates on one side and the other. This advocacy is usually most strenuous in the beginning, as testified to by the early discussions of the relative merits of high-speed and low-speed engines, of vertical, triple, crank and fly-wheel pumping engines, and the horizontal triple direct-acting type. Usually a more intimate knowledge, resulting from experience, teaches us that each device or material has its place and its proper usage. I think this is so with cast-iron and riveted steel pipe. In discussing their relative value, several items must be given consideration. I may say here as in the case of Mr. Hazen's paper that I am confining my remarks to the relative value of cast iron and steel for large supply mains, as nothing has been developed which so readily adapts itself to street distribution mains of smaller size as does cast iron.

Cost is the first thing to be considered. In first cost steel mains of large size are cheaper than cast-iron mains.

As a rule they are more easily handled, due to the fact, that the walls of steel pipe are thinner than cast iron pipe, and hence steel pipe is lighter. This factor is of material importance where long lines of supply main are laid through a rugged country distant from transportation facilities.

The question of strength is one of design; and in making comparisons it should be assumed that both the cast iron and riveted steel pipe will perform the function for which they are designed.

From the data available, it appears that the cost of maintenance and depreciation on cast-iron pipe is less than on riveted steel pipe. The data, at hand, however, are not sufficient to enable one to say definitely that the difference is sufficiently great to offset the difference in interest charges resulting from the additional first cost of the cast-iron pipe. Interruptions to service, where a community depends upon a single supply line, resulting from repairs as a result of corrosion, are usually of more importance, however, than the mere consideration of cost.

Originally, the so-called riveted steel mains were built up of wrought iron, and from the best evidence at hand, it appears that wrought iron pipe offers a greater resistance to corrosion than does the pipe of more recent date, fabricated from steel plates. It must be remembered, however, that wrought iron is not a definite thing by any means. Its character depends upon its chemical composition, and this in turn upon the composition of the pig iron from which it is made, and the care and skill with which its fabrication has been conducted. The elements affecting it are silicon, carbon, manganese, phosphorus and sulphur. Experience has shown that the more nearly steel approaches a pure iron, the longer it resists corrosion. The properties of wrought iron are the nearest approach to pure iron notwithstanding its slag. This is because the slag is mechanically mixed and does not interfere with the chemical properties of the product.

Investigations by a committee of the American Society of Testing Materials have failed to produce any conclusive evidence with regard to the relative rapidity with which wrought iron and steel corrode. So many elements seem to affect the rate of corrosion. Field experience, however, indicates that the riveted pipe of wrought iron is more resistant than steel. In considering this question, it must be remembered that it is difficult to obtain wrought iron plate at this time, and that in specifying riveted or lock bar pipe, low carbon steel should be considered.

Cast iron is more highly resistant to corrosion than either steel or wrought iron.

Corrosion is due not only to the character of material of which the pipe is made, but also to the character of the soil in which the pipe is placed, and the character of the protective coating placed on the pipe. The thickness of the shell is of material importance in considering the effects of corrosion. Steel pipe being only about one-third as thick as cast iron, will show the ultimate effects of corrosion in about one-third the time required for such effects to develop on cast-iron pipe, at the same rate of corrosion. As a matter of fact, every examination which I have made of steel and cast-iron mains, laid under the same conditions, has fairly demonstrated the greater resistance of cast-iron pipe to corrosion.

The greater resistance of cast-iron to corrosion than steel is probably due, in a large measure, to the silicious coating which it receives when the molten metal is poured into the mold. This silicious coating adheres very firmly to the pipe. Also the roughness of the exposed surface of the cast iron offers a firmer foundation for the coating than does the smooth surface of the steel pipe, and hence the same coating applied to cast iron is usually more durable than when applied to steel pipe.

We have much data with relation to the life of cast-iron pipe. We know that it is good for a hundred years when properly coated, and under almost any conditions of soil. There are instances of much longer life.

The intake pipe at the first pumping station for supplying Paris, which extended into the river Seine, and which was laid in 1802, after an immersion lasting for over a century, was recently removed and was found to have been in such good condition that it might have been relaid. The lettering on the pipe was not disturbed. Instances of cast iron pipe laid in Europe as early as 1765, which is now in serviceable condition, have been recorded. The speaker has removed cast-iron pipe from low ground saturated with a salt solution which has been in service since the early part of the last century and which was in excellent condition when removed. There appears to be no practical limit to the endurance of cast-iron pipe and its resistance to ordinary corrosion.

In considering the effects of corrosion, reference must be made to the effects of chlorides, nitrates and sulphates, which are found in soils of high organic content, and in marsh lands adjacent to salt

water. Weak solutions of these salts will produce harmful effects, proportionate to the rapidity with which a material will corrode. A minute quantity of soluble salts is sufficient to start corrosive action and a material which is liable to corrosion should not be placed therein.

Some reference has been made to the life of cast iron pipe. Our experience with riveted steel pipe is very much more limited but there are examples which tend to show that lines of riveted steel pipe, constructed within the last twenty years, have materially depreciated and great trouble has been experienced from the effect of corrosion. These effects seem to proceed more rapidly in clay soils and marsh land than in sand. Among the pipes which have thus been affected, is the second Hemlock Lake conduit here in Rochester, which was laid in 1893: The Portland, Oregon, conduit, the Atlantic City conduit, and certain conduits laid in the marshes of the Hackensack meadows in New Jersey.

Before concluding, attention is called to the effect of electrolysis upon wrought iron or steel. It is manifestly more rapid on steel pipes than cast-iron pipe, for the reason that steel will corrode more rapidly than cast iron, and electrolysis may be defined as a more serious form of corrosion, occurring where an electric current leaves the pipe and which, in so doing, sets up corrosive electrolytic action. This action depends, in amount, upon the volume of the current, and on the chemical and physical character of the soil; only a very slight difference in potential is essential. Thus electrolytic corrosion is much more serious in wet clay or in salt marshes, than it would be in a dry and sandy soil.

Rolled steel plates, as compared with cast iron, although the cast iron is several times as thick, will, owing to the higher conductivity of steel, have from one to three times the conductivity of a cast-iron pipe designed for the same pressure. This is important, as the electrolytic action has been stated to be mainly dependent upon the volume of the current, and hence in territories where street railway currents are returned over pipe lines, the riveted steel pipe offering a better conductor will carry more current, and hence electrolytic action will be aggravated on this account.

The injury to water mains, and other sub-surface conductors due to electrolytic action, occurs only where the conductor or pipe is positive to the ground. In other words, electrolytic damage to water mains, or other metallic sub-surface conductors, is caused only where an electric current leaves them, and not where it enters them.

The trolley currents pass out from the power station over the overhead feed wires, and trolley wires, and thence through the trolley poles and the motors in the cars to the rails, and should return through the rails. When the rails are insufficient in area, or when they are imperfectly bonded, these currents return through water mains and other pipes, through the earth, the water courses and the river banks, back to the power station. Every material which will carry an electric current from the rails to the power house will carry some of this current. The amount of current thus carried will depend upon the size and conductivity of the water mains or other sub-surface conductor, as well as upon the electrical condition of the trolley rails. It is apparent, therefore, that the conductivity of the material of which a water main is constructed is an important element, affecting the amount of electrolytic action which will occur, at points where the current leaves the pipe in its effort to find the path of least resistance. Under conditions where electrolysis is liable to occur the metal of the greatest electrical resistance is preferable, other things being equal. This is true where the resistance to corrosion is the same—if the metal with the greatest conductivity also corrodes more rapidly then, it is still less suitable for places where electrolytic corrosion is liable to develop.

As the division of current will occur in proportion to the resistance offered by the several available paths for the return of the current to the power station, it is also obviously true, that even if the bonding is good, and the cross section of the rails is large, the tendency is for the return current to divide itself between the rails and the other conductors, adjacent to the street railway tracks, and hence the complete isolation of return trolley currents is almost impossible. It is only possible to mitigate results by reducing the amount of current leaving the rails to a minimum.

The return may be straight, if these return conductors lie in a direct line, between the point where a current leaves the rail and the power station, or the road may be extremely circuitous. If there are a number of roads, current will be taken through all, the larger part taking the best conductor. It must be remembered, that a current which is found flowing in a pipe, not electrically connected with the negative buss-bar at the power station, must leave it at some point to return to the negative buss-bar, and hence to the negative pole of the generator. This follows from the fact that every electric circuit must be completely closed, so that every ampere which leaves the positive pole of the generator, must eventually return to the negative

pole, no matter how long or complicated the path through which it passes may be.

There are few places of any size, in which the suburbs are not, at the present time, traversed by numerous suburban lines. If the mains pass in the vicinity of these lines, they may absorb their proportion of the return trolley current and deliver it to the ground at some point nearer the power station. This was clearly demonstrated to me in a recent survey of certain steel and cast iron pipe lines laid in the marshes of the Hackensack meadows. I found that these pipes were carrying quite an appreciable quantity of current from distant points to the power station, and that they were unloading it in the marshes, to be returned through the saturated soil, to the power station. The result of these surveys indicated the superior conductivity of the steel pipe, and the much greater corrosion resulting from the effects of electrolytical action, than in the case of the cast iron mains.

In summing up, it may be said that where first cost is of prime importance, steel may be used on large supply mains. Second, where the difficulties of transportation are serious and the cost of hauling is heavy, expediency may call for the use of this material. Third, in sections where dry sandy soil is encountered, one would be justified in securing the benefit of reduced first cost by recommending steel pipe. Fourth, in clay and wet soil, such as marshlands and meadows, particularly where the presence of salts in solution increases corrosion, riveted steel pipe should not be used. Fifth, where pipe is laid in wet soil and will be subject to electrolysis, cast iron should be used. Sixth, where permanency is a prime consideration, our present knowledge indicates that cast iron is preferable.

H. F. Dunham (by letter): Many years ago when the price of cast iron pipe was much higher than it is now an able engineer designed and built a supply main many miles long to bring water from Ludlow to Springfield. Although foreign to the subject under discussion, since the material was neither cast iron nor steel, it might be of interest to publish possibly as an appendix to this valuable paper some of the more important data about that pipe line. The general design, material used, manner of doing the work, length of time and the conditions under which the pipe was in service and especially the yearly sums expended for repairs and maintenance would interest many members of this Association. The amount saved to the city in interest might be referred to.

The line was intended to be simply a gravity line but in periods of extreme drought pumps were used at intermediate points with the liability of introducing shocks and air troubles that may have increased the expense of maintenance.

The annual reports of the water commissioners doubtless show expenditures for repairs and the amounts paid for damages when breaks occurred. The rate of increase in such necessary expenditures year by year might be noted to show the rate of deterioration.

The state of the Cement Art at the date of that construction was far below its present place. Great changes too and improvements have been made in the iron and steel industry.

If it be a proper inquiry one might ask what kind and length of service could have been expected from a pipe line of similar construction from the Westfield district if advantage had been taken of the improved modern materials and of the ingenuity, skill, and thoroughness for which the work of the author's firm is so widely noted. After a few words about adaptation and permanence the estimated cost compared with cast iron and steel might be mentioned.

HOT WATER TROUBLES

By George C. Whipple

When one considers the fact that most houses that are supplied with running water are equipped with hot water services as well as cold, and that a very large percentage of domestic water consumption is drawn from the hot water taps, it is rather surprising that the quality of hot water has been discussed so seldom by water works engineers. Perhaps this is because hot water is almost never used for drinking; perhaps it is because such troubles as have arisen have been deemed to fall within the province of the plumber rather than that of the engineer; perhaps it is because the troubles have been so intermittent, so localized and so various in character that general causes have not been sought for. Whatever the reason may be for the poverty of engineering literature on the subject, it has been a matter of common knowledge for many years that the heating of water and its passage through boilers, tanks and pipes of various metals often has a marked effect upon its quality. Conversely, hot water often has a material influence on the structures used for heating and carrying it.

The writer very well remembers that as a boy he was warned against drinking water from the hot water faucets. The water was heated in a cast-iron water back in the range and distributed through a copper boiler and lead pipes, and the obvious reason for the prohibition was fear of poisoning by these metals. With the particular water used there was some reason for this warning, but in general the hygienic aspect of the case may be ignored, largely for the reason that no one likes the water to drink.

The hot water troubles usually met with are not of a hygienic character, but are physical. They are largely problems of corrosion. Yet they are practical problems, and in a number of instances that have come within the observation of the writer, they have been of a serious character. When, with the cold water satisfactory, the hot water becomes too rusty to be used for bathing, when marble bowls become discolored, when clothes in the laundry become stained, when pipes become choked with iron rust, or become so weakened through corrosion that they have to be replaced, when tenants leave

their apartments and when even the most long-suffering citizens complain of the water service, the situation well deserves the name "red water plague" that has come to be applied to it. And when such phenomena follow a change in the water supply or changes in the method of heating and distributing the hot water, the subject is one worthy of serious investigation by water works engineers. It is hoped that the present paper will be an introduction to a wide discussion of the whole matter.

TEMPERATURE REQUIRED FOR DOMESTIC SERVICE

The hot water required for domestic service need not ordinarily have a temperature above 140° F. For most purposes hot water as it is used has a lower temperature than this. For washing the hands or for bathing, temperatures of 100° to 105° are agreeable. Few people can comfortably bear their hands in water above 115°. For dish washing a somewhat higher temperature is preferred by many, say 140°. About the same temperature is demanded for washing clothes where the laundry is provided with a stove and boiler for scalding. In apartment houses not provided with laundries and where all the washing is done in set tubs, higher temperatures are the rule, and they often run well above 150°—in fact, sometimes the tap water seems to be almost boiling. The range of temperature observed in hot water systems therefore varies all the way from the temperature of the cold supply nearly up to the boiling point.

QUANTITY OF HOT WATER USED

Very little is known about the quantity of water that passes through the hot water systems of our houses, but it certainly is a substantial proportion of all the water used for domestic purposes, often a quarter or a third of it and sometimes more. Through the courtesy of Mr. E. E. Lochridge, Chief Engineer of the Water Department of Springfield, Mass., the following figures are presented (Table 1), showing the consumption of hot water in an apartment house in which reside fourteen families, comprising fifty persons. These figures indicate that during the two winter months covered by the measurements, about 42 per cent of the water used passed through the hot water system. The amount of hot water used is greater in winter than in summer.

TABLE 1

Consumption of Hot and Cold Water. Apartment House in Springfield, Mass., Containing Fourteen Families and Fifty Persons. January 17–March 7, 1911. (From E. E. Lochridge, Chief Engineer of Water Dept.)

WEEKLY PERIOD	WATER CONSUMPTION GALLONS PER CAPITA DAILY			PERCENT WHICH HOT WATER WAS OF TOTAL CONSUMPTION
	Cold water	Hot water	Total	
Jan. 17–24	56.9	34.2	91.1	37
Jan. 24–31	50.2	33.5	83.7	40
Jan. 31–Feb. 7*	39.3	30.0	69.3	43
Feb. 7–14	40.8	28.3	69.1	41
Feb. 14–21	38.9	31.6	70.5	45
Feb. 21–28	35.6	23.6	59.2	40
Feb. 28–Mar. 7	38.5	33.2	71.7	46
Average	42.9	30.6	73.5	42

*Pressure reducer set on Feb. 3, 1911.

There is often a large amount that flows to waste before the water runs warm from the taps. This wastage varies greatly according to the system of distribution employed, the state of the fire in the heater, the water pressure, etc. It may easily exceed the actual use. Furthermore, if the hot water pipes are laid below and close to the cold water pipes, the cold water may become luke-warm and a wastage from the cold water faucets may result when water is wanted for drinking. With the introduction of meters there has been a naturally increasing tendency to provide circulating systems of hot water pipes, so arranged that hot water is almost constantly available at the tap without one being obliged to let the water run.

METHODS OF HEATING

In private houses the source of heat is commonly the kitchen range, which is provided with a cast-iron water-back, or water-front, or with brass pipes laid around the fire box. Sometimes the furnace is used for this purpose during the winter. Recently gas heaters have become largely used. These consist of a coil of copper pipe surrounded with a metal jacket, the water flowing through the pipe and the heat from the gas flame impinging on it from without. In apartment houses and hotels special cast-iron heaters are provided for this service alone, or the water is heated by steam coils placed inside the storage tank. The apparatus is placed in the cellar and cared for by the janitor. In all cases the hot water system includes

a storage tank, which in private houses is commonly known as the kitchen boiler. In private houses the hot water service is somewhat intermittent, but in apartments a constant supply is supposed to be maintained at all times, although during the night it is common to bank the fires and reduce the heat.

There are two systems of supplying water to the heaters in separate dwellings, known as the *tank system* and the *pressure system*. There are likewise two methods of distributing the water, the *direct method* and the *circulating method*.

THE TANK SYSTEM

According to this system the water from the street mains is delivered into an attic tank above all fixtures. This tank is open to the air and is provided with a ball cock inlet and an overflow so that a constant water level is maintained. From the attic tank a pipe leads to the bottom of the boiler and this connects with the waterback. The hot water system thus has a uniform pressure, which is less than that of the city mains. An important feature of the tank system is the expansion pipe that commonly extends upward and is turned over and pointed downward into the attic tank. This serves two purposes, namely, that of taking care of the expansion of the water during heating, and providing a means for a partial discharge of any air that may be liberated in the hot water system.

THE PRESSURE SYSTEM

With the pressure system there is no attic tank and the entire hot water system is under the pressure of the city mains. The supply is taken direct from the house supply to the bottom of the boiler. No expansion pipe is needed, but provision has to be made to prevent back siphonage of the boiler, which may occur under certain conditions. A stronger kitchen boiler is needed when the pressure is high. A good many years ago, when the kitchen boilers were ordinarily of copper, the tank system was largely used in private houses, but the stronger and cheaper steel boilers have enabled the pressure system to be readily used. Tanks are sometimes preferred where the city pressure is high. As there is no expansion pipe there is no outlet for air save through the taps. The two diagrams, Fig. 1 and Fig. 2, illustrate the general arrangement of pipes for the two systems as applied to an ordinary dwelling.

CIRCULATION

The pipes of the distribution system are arranged in accordance with the well known principle that warm water is lighter than cold water and tends to rise. The cold water inlets are at the bottom of the boiler and water-back, the hot water outlets are at the top. The horizontal pipes are sloped slightly upward in the direction of flow for the hot water and downward for the cold water.

When the hot water is distributed by the direct method the service pipes extend from the top of the boiler to each fixture. If not drawn upon continually, the water in these pipes becomes chilled and hot water cannot be obtained until the chilled water has been first drawn off. Where the circulating method is used there is a return pipe from a point near each fixture to the boiler, so that hot water is continually circulating through the system. By this method hot water can be obtained at the taps more quickly and the waste of water is lessened. The two methods are illustrated by Figs. 3 and 4.

APARTMENT HOUSE SUPPLIES

In modern apartment houses and hotels of moderate height, the pressure system is generally used and also the circulating method of distribution. Separate kitchen boilers are replaced by a large storage tank in the cellar, located near the heater, or itself heated by steam coils. The general arrangement of a tall apartment house hot water system, in which the water is heated with a small cast-iron stove, is shown in Fig. 5.

HOT WATER SUPPLY FOR TALL BUILDINGS

In the case of very tall buildings, such as apartment houses, hotels, and office buildings, where the city pressure is not sufficient to force the water to the upper floors, it is necessary to provide a booster pump in the building. When this is done the tank system is commonly used, the tank being placed on the roof. Another method is that of using a closed storage tank in the basement, the air being compressed in the upper part of the tanks. This method, commonly referred to as the pressure system, or the Kewanee system, has the advantage of dispensing with the roof tank.

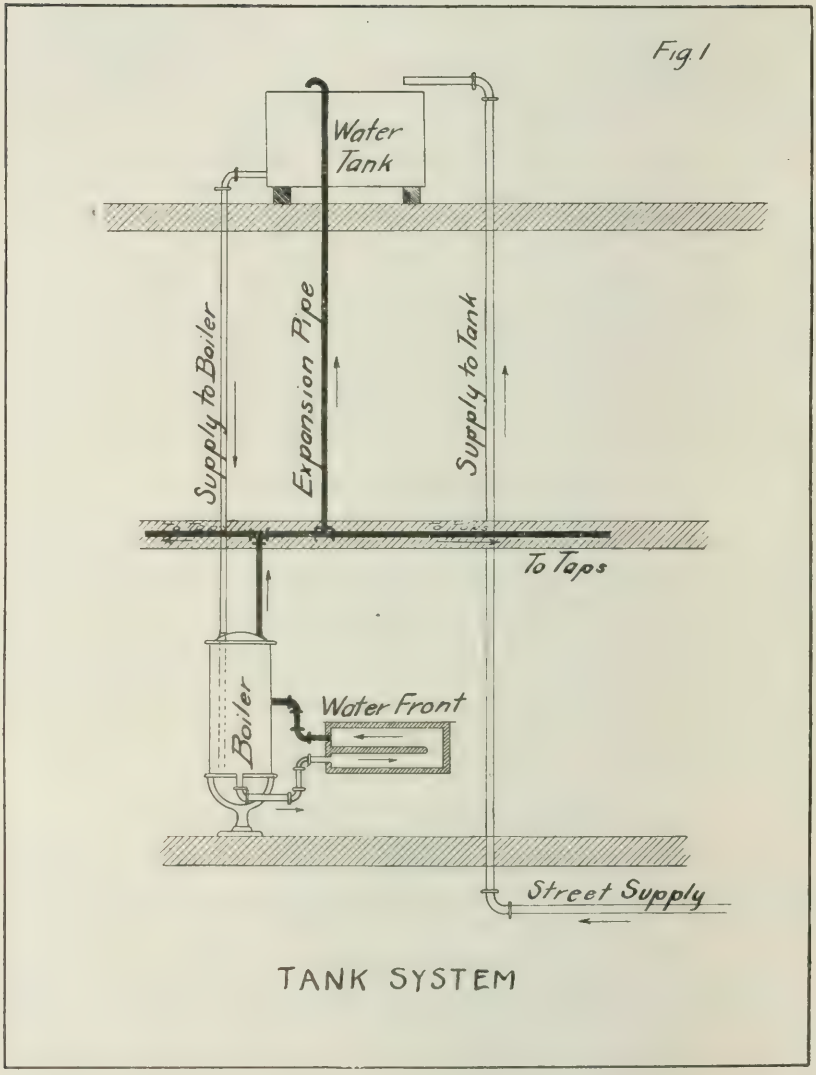
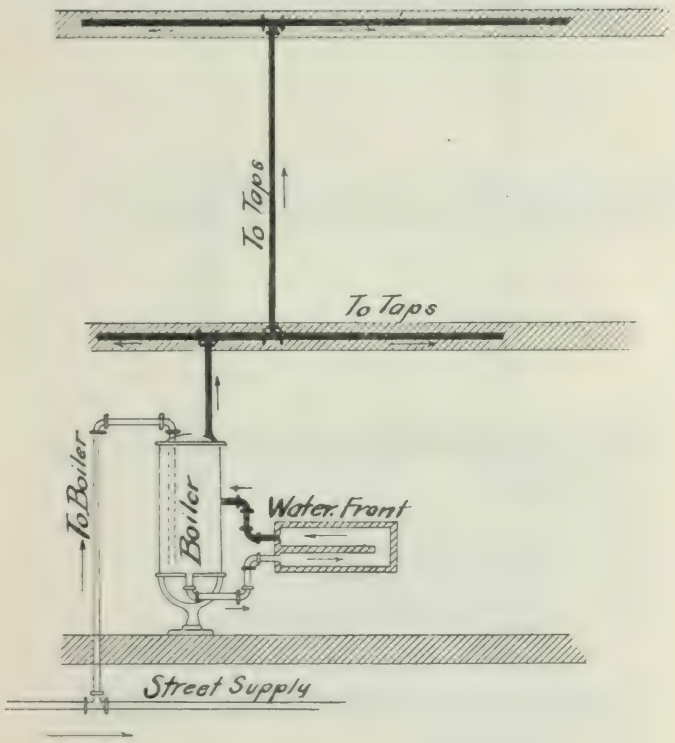


Fig. 1
Water Tank
Supply to Boiler
Expansion Pipe
Supply to Tank
To Taps
Boiler
Water Front
Street Supply

TANK SYSTEM

Fig. 2



CITY PRESSURE SYSTEM

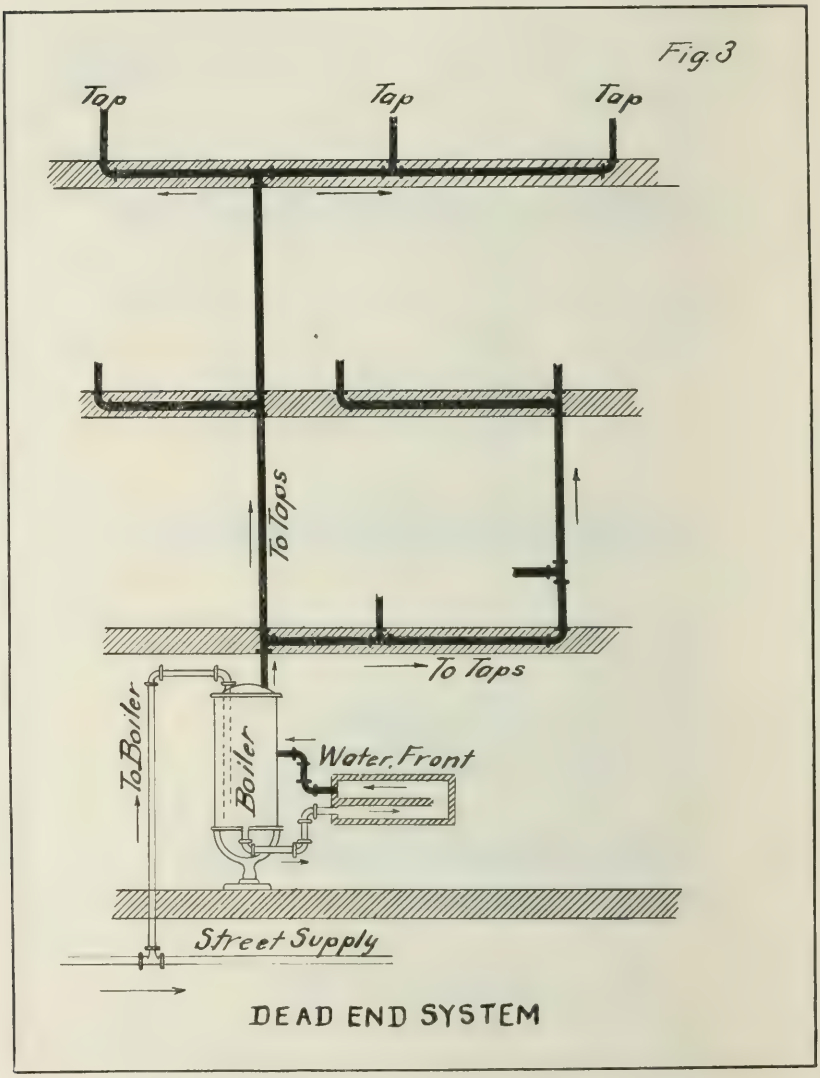


Fig. 3
Tap
Tap
Tap
To Taps
To Taps
To Boiler
Boiler
Water Front
Street Supply
DEAD END SYSTEM

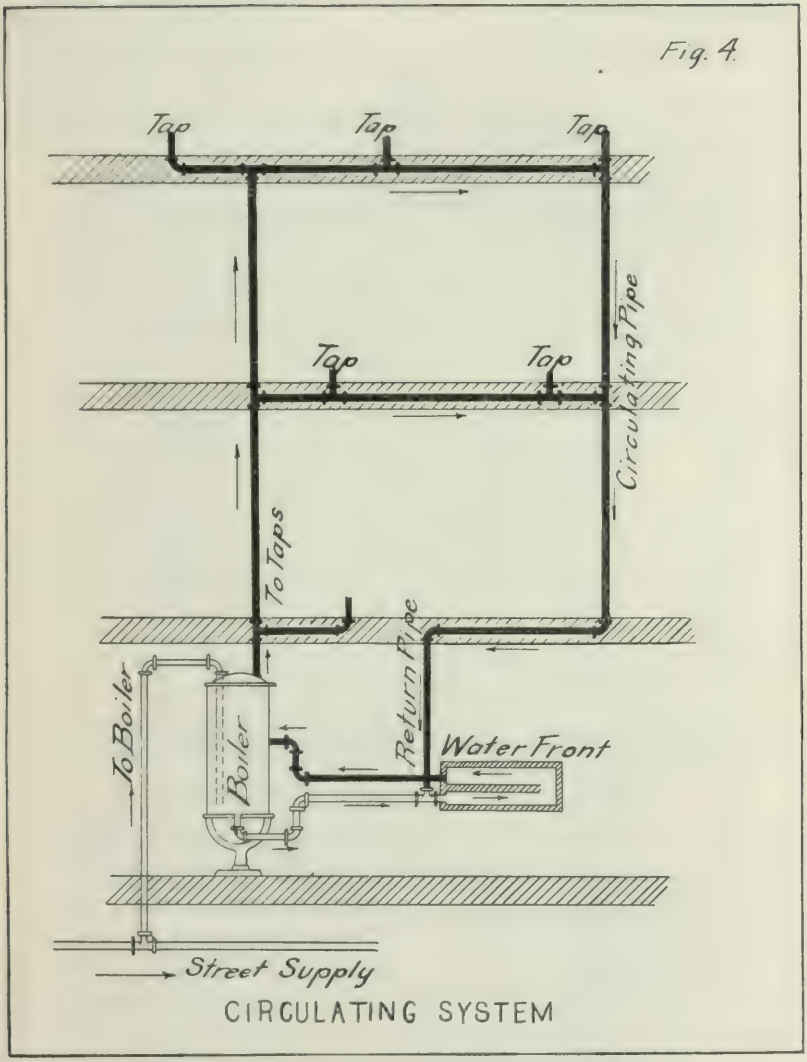
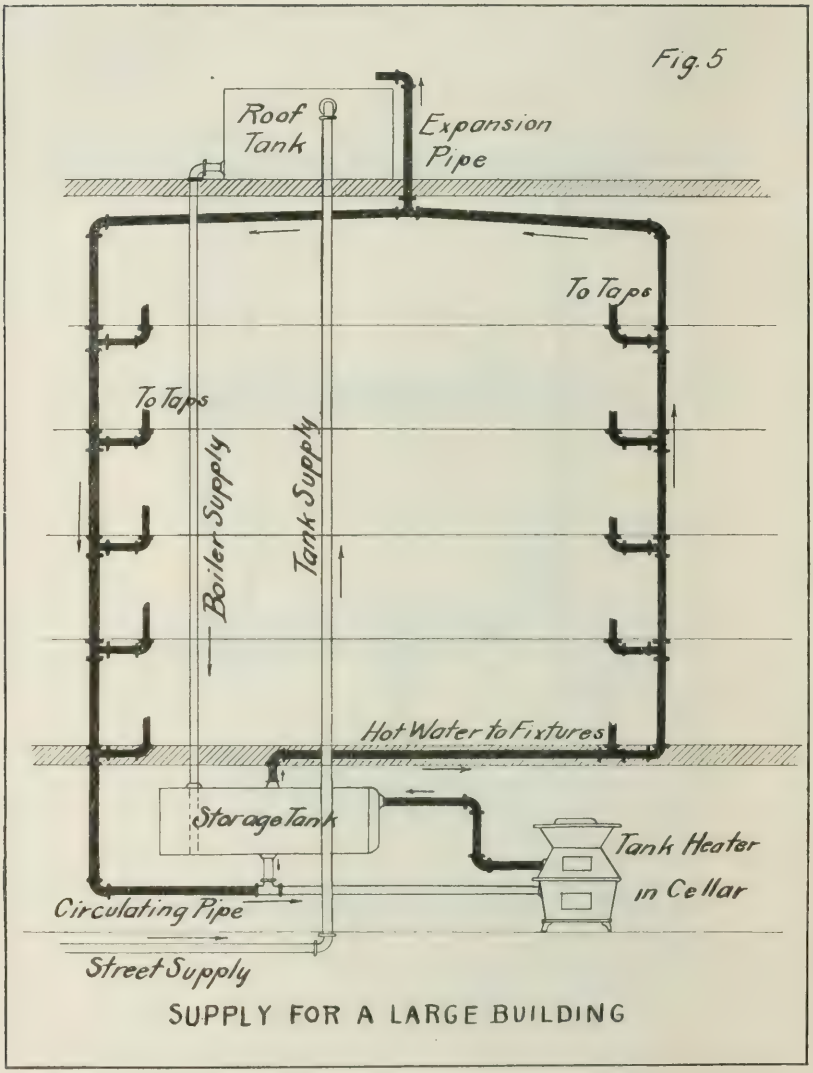


Fig. 4.
Tap
Tap
Tap
Tap
Tap
Circulating Pipe
To Taps
Return Pipe
Water Front
To Boiler
Boiler
Street Supply
CIRCULATING SYSTEM



SUPPLY FOR A LARGE BUILDING

MATERIALS OF CONSTRUCTION

The water-backs and water-fronts in kitchen ranges are made of cast iron. The pipes in ranges are usually of brass. In gas heaters copper pipes are used. The special heaters used in apartment houses are made of cast iron. In the tanks heated by steam the pipes are made of brass, wrought iron or steel.

Formerly the kitchen boilers were quite generally made of copper and this metal is still used somewhat where the water is soft and where the pressures are low, as in the tank system. For the pressure system stronger boilers are required, made of wrought iron or steel, most commonly of galvanized steel. The storage tanks used in apartment houses are also made of wrought iron or steel. In high-class installations they are galvanized.

The distribution pipes are made of brass, lead, and galvanized wrought iron or steel. Brass is used in the best installations and is necessary for some waters. With other waters galvanized wrought iron or steel gives satisfaction and are cheaper. Lead is now used but little on account of its increased cost. Not infrequently a combination of metals is used, brass being employed for the pipes between the range and the boiler and wrought iron or steel for the service pipes between the boiler and the separate fixtures. Tin-lined lead pipe is used to a limited extent, but Weston has shown that the tin lining fails to protect the lead from corrosion. In some places an alloy of lead and tin is said to be used. Altogether perhaps the most important fact to be reckoned with is the greatly increased use of steel pipe during the last few years.

EFFECT OF HEATING ON THE QUALITY OF WATER

Water drawn from the hot water taps and cooled is likely to have what is termed a "flat" taste. This is due in part to a decreased oxygen content and is somewhat more marked in houses where the tank system is used, that is, where an opportunity is provided for air to be discharged. The flat taste may be due, also, in some instances, to an increase in the amount of iron and to the effect of heat on the organic matter present. If the cold water contains algae, heating tends to increase its odor, as it breaks up the organisms and drives out the oily substances that produce the odor. In other cases the odor of water may be increased on heating by liberation of dissolved gases. This is noticeable in polluted waters. This increased

odor of the hot water over the cold water is a common phenomenon in nearly all surface supplies, especially during the summer.

Heating a surface water also tends to increase its color and sometimes its turbidity. That is, a deposit of sediment may take place in the tanks when the flow is small and be subsequently washed out when the draft is large.

It is hardly necessary to discuss here the effect of heat on the sanitary quality of water, as hot water is used so seldom for drinking. From the bacteriological standpoint, heating would tend to destroy germ-life and make the water safer for use, but this ought not to be depended upon. Where lead pipe is used, especially with a soft, corrosive water, the danger of lead being taken into solution is increased. Such a water continuously used for drinking might give rise to lead poisoning.

RUSTY WATER

More important than the direct effect of heat on the quality of the water is that of the reaction that occurs between the water and the pipes, boilers, heaters, etc., in which it is heated and through which it flows. This leads to the general subject of the corrosion of metals by water and the effect of heat upon such action.

Very few of the red water troubles are caused by the iron naturally present in the water or by the action of the water on the street mains, but rather by the corrosive effect of the water on the tanks and service pipes through which the water flows. There are, it is true, instances where, by reason of the presence of chlorides or an excessive use of alum, the water has a corrosive effect on the street mains and house service pipes and causes the water to be rusty. Such conditions are somewhat rare and when observed, both the cold water and the hot water are affected. It is not these conditions, however, that are ordinarily referred to when the term "red water plague" is mentioned. In this case the cold water is not appreciably affected, but the trouble is confined almost exclusively to the hot water service. One exception may be noticed. It sometimes happens that for one reason or another hot water is forced backward into the cold water pipes, thus causing the trouble originating in the hot water system to extend to the cold water taps.

THEORY OF CORROSION

According to the modern and now generally accepted theory, the corrosion of iron by water and the formation of iron rust require

first, the presence of hydrogen ions in the water and, second, the presence of dissolved oxygen. Hydrogen ions are electrically charged atoms of hydrogen. All acids form them by dissociation. Whenever they are present in solution that solution possesses acid properties. They attack the metallic iron, which is dissolved in a ferrous condition. The oxygen dissolved in the water then oxidizes this ferrous iron and iron rust is formed. Under certain conditions this precipitates at once. Under other conditions it apparently exists in a colloidal state, that is, in an extremely fine state of subdivision with its particles electrically charged, and precipitates only when this electrical charge is neutralized. Very little is known about this phenomenon. Certain substances tend to prevent the precipitation of colloids. Thus, peaty, organic matter tends to prevent the precipitation of iron.

Iron has a natural tendency to dissolve in water as the hydrogen ion is always present in some degree. Pure water, therefore, by its dissociation tends to act as a weak acid. Even in the purest distilled water there is a splitting up, or dissociation, of some of the molecules of water (H_2O) into the hydrogen ion ($\overset{+}{H}$) and the hydroxyl ion ($\overset{-}{OH}$). Distilled water therefore acts as an acid. Iron will be dissolved, and rust will form if oxygen is present. Whatever increases the number of hydrogen ions in water increases its corrosive power. Acids do this to a marked degree. Whatever decreases the hydrogen ions reduces the corrosive power. Alkalis do this. When alkalis are ionized, the hydroxyl ion ($\overset{-}{OH}$) is formed, and, as it has an opposite electrical charge from the hydrogen ion ($\overset{+}{H}$), neutralizes it. Thus, carbonic acid, H_2CO_3, (or $H_2O\ CO_2$), when dissociated, forms $\overset{+}{H} + \overset{-}{HCO_3}$, while lime ($CaO_2\ H_2$) forms $Ca + 2\overset{-}{OH}$.

A further conception of the phenomenon of iron rusting is that often referred to as "the electrolytic theory of corrosion." According to this theory a sort of battery action takes place in the water and a current of electricity is set up between the metallic iron at one spot and some other metal or some impurity in the iron at some other neighboring spot. This action demands that the water be to some extent a conductor of electricity, that is, it must contain electrically charged ions, and the higher the conductivity the greater will be the current. The result of this action is that the hydrogen ions give up

their charge of electricity to the iron, which goes into solution, while gaseous hydrogen collects on the surface of the metal. As this gaseous hydrogen is a non-conductor, the iron becomes covered with a film of hydrogen, or is polarized, so that after a time the action tends to cease. Whatever removes the hydrogen from the metal depolarizes it and causes the action to continue. The presence of oxygen in water does this, as it unites with the hydrogen to form H_2O, or water. A circulation of water containing oxygen, whether brought about by mechanical agitation or by thermal currents, also tends to remove the hydrogen. Oxygen therefore aids the corrosion of iron in two ways, by depolarizing it and by oxidizing the iron that goes into solution.

The presence of other metals also affects the corrosion of iron by increasing the difference of potential, and therefore the strength of the electrical currents. This is termed galvanic action. The metals act differently in regard to the direction of the electrical currents between them and iron. Some cause the positive current to flow towards the iron, and some away from it, that is, some hasten the corrosion of iron and some retard it. The common metals are arranged in the following order of what is called the potential series: aluminum, manganese, zinc, iron, nickel, tin, lead, hydrogen, copper. Each metal tends to protect the other metals in the series below it from going into solution, but in doing so it itself tends to dissolve. Thus, zinc protects iron. On the other hand, copper acts in an opposite way, and increases the solution of iron. Weston has recently shown by experiments on tin-lined lead pipe that the tin does not prevent the lead from going into solution. With two metals present, whatever increases the electrical conductivity of the water increases the corrosion of one metal or the other. Substances that when dissolved in water carry a charge of electricity and thus increase its conductivity are termed electrolytes. A typical example of this is sodium chloride. Electrolysis is an important element in various water works problems, as the members of this association well know.

CLASSIFICATION OF WATERS

The water supplies with which the red water plague has been observed may be classified as follows:

Class 1. Very soft ground waters.

Class 2. Waters in which the chlorides or the free carbonic acid are high as compared with the alkalinity.

Class 3. Very soft surface waters that are relatively high in color and contain peaty, organic matter and free carbonic acid.

Class 4. Relatively soft waters, especially high-colored waters, with which sulphate of alumina is used as a coagulant but which are not overdosed so far as the alkalinity is concerned.

Class 5. Waters overdosed with sulphate of alumina so as to render them acid.

Class 6. Waters containing originally excessive amounts of iron.

SOFT GROUND WATERS

Some of the ground water supplies on Long Island are troubled with rusty hot water. These waters are invariably soft. In some cases the chlorine is rather high, varying from 10 to 25 parts per million. The dissolved carbonic acid is also high and dissolved oxygen is present. Other waters on Long Island taken from neighboring wells and similar in character, except that the hardness is high, may cause little or no rusty water. In some, oxygen is lacking.

The water supply of Far Rockaway is a ground water, aërated and filtered through a sand filter to remove the iron. The process is extremely successful and the filtered water rarely contains more than 0.1 part per million of iron, often none. The chlorine in the water is generally about 7.0 parts per million. The hardness varies from 12 to 15 and the alkalinity, from 7 to 12 parts per million. The amount of carbonic acid in the filtered water is presumably low, on account of the aëration. A number of instances of rusty hot water have occurred with this supply.

The ground water supply of Garden City, L. I., is somewhat troubled with rusty water. At the Garden City Hotel the marble bowls in the toilet room are at times stained beneath the hot water faucets, no stains being found, however, under the cold water faucets. On May 23, 1910, samples of hot water and cold water collected at this hotel were analyzed by Melville C. Whipple, with the following results:

	PARTS PER MILLION	
	Cold water	Hot water
Temperature	80 F	102 F
Color	0	9.0
Chlorine	11.5	12.0
Hardness	27.0	27.0
Alkalinity	5.5	
Carbonic Acid	28.0	29.0
Dissolved Oxygen	9.34	8.02
Nitrates	2.90	2.80
Iron	0.20	0.30

For purposes of comparison, the following analyses of samples of water collected October 29, 1909, at Flatbush, L. I., also supplied with ground water, are given below. This supply gives no trouble from rusty hot water.

	PARTS PER MILLION	
	Cold water	Hot water
Turbidity	0.00	0.00
Color	0.00	10.0
Chlorine	22.5	23.5
Hardness	146.0	146.0
Alkalinity	94.0	94.0
Free carbonic acid	12.0	8.5
Dissolved oxygen	5.6	3.7
Nitrates	5.5	5.5
Iron	0.2	1.1

It will be seen that this water contains more chlorine but somewhat less dissolved oxygen and carbonic acid than the Garden City water. The water is hard. It will be noticed that the amount of iron in the hot water was about five times as large as that in the cold water, and was much larger than was found in the hot water at Garden City, yet the Flatbush water does not give any precipitation of iron rust when the water is heated. This may be due to the protective action of the carbonates producing the high alkalinity.

WATERS IN WHICH THE CHLORIDES ARE HIGH BUT THE CARBONATES LOW

Many waters of this class exist along the East Atlantic Coast. As an example, the water supply of a village a few miles north of Camden may be referred to. An analysis of this water, made on April 18, 1905, showed that the chlorine was high but that the carbonates were low. The water as taken from the wells contained an insignificant amount of iron, but the water in the houses was at times more or less rusty.

	PARTS PER MILLION
Turbidity	0.00
Color	0.00
Total solids	105.00
Nitrates	5.20
Chlorine	19.20
Total hardness	40.50
Alkalinity	14.50
Incrustants	26.00
Iron	0.05

The water supply of Oswego, N. Y., is taken from the Oswego River. It is very hard and very saline, as the river drains the Syracuse salt deposit region. A sample collected January 10, 1908, gave the following analysis:

	PARTS PER MILLION
Total hardness	189.0
Alkalinity	96.0
Incrustants	93.0
Chlorine	70.0
Iron	0.3

Although the river water contained comparatively little iron, the tap water was often very rusty, both hot and cold. This rusty condition of the cold water as well as the hot water seems to be somewhat characteristic of this class of supplies and serves to separate them from the soft waters in which the corrosion is found chiefly with the hot water. Water supplies of beach hotels, being located near the sea-coast, are not infrequently affected in this way.

SOFT COLORED WATERS

It is a well known fact that soft surface waters corrode the metals used for service pipes. This matter has long received attention in connection with the subject of lead poisoning. The soft, peaty water supplies obtained from the English moorlands act on lead pipes, sometimes to a serious extent. In a number of English cities, such as Birmingham, Sheffield, and elsewhere, lime is added to the water to prevent injury to the public health from lead poisoning and to avoid the inconveniences attending the corrosion of other metals.

In a recent paper presented to the Institute of Civil Engineers of Ireland, by W. Kaye-Parry, an account is given of the corrosive effects of the Vartry supply of Dublin. The author says:

> We all know by experience that since the Vartry water was introduced into Dublin it has become necessary to discard both iron boilers and iron pipe for hot water supply, owing to the destructive action of the water on the iron. A galvanized iron cylinder in which hot water is stored is very soon perforated, and for this reason copper cylinders are now almost always used.
>
> This action, it is claimed by Dr. Adeney, is "due to the presence of minute quantities of peaty matter which undergoes slow fermentation with the formation of carbonic acid as well as small quantities of nitric acid."

In 1900 Clark and Forbes, chemists of the Massachusetts State Board of Health, published a report on the corrosion of service pipes

in which the effect of dissolved carbonic acid was found to be of controlling importance. The action was found especially severe when the carbonic acid was high and the water soft.

Rusty hot water has been observed to some extent in New York City. The Croton water is somewhat harder than the waters of New England, although it cannot be fairly classed as a hard water. Galvanized iron and steel pipes are largely used for the hot water services. Dr. Ira H. Woolson has recently called attention to the rusting of both iron and steel pipes in various public bath-houses of the city (*Engineering News*, December 8, 1910). This has also been noticed in some of the larger hotels and to some extent in private residences. Generally speaking, however, the New York City water has not caused serious trouble in this way. The following is a typical analysis of Croton water as to certain constituents.

	PARTS PER MILLION
Color	25.0
Chlorine	1.8
Hardness	35.0
Alkalinity	30.0
Iron	0.2
Nitrates	0.15
Dissolved carbonic acid	3.0

In many New England cities supplied with soft surface water, experience has led to a very general use of brass and lead pipe for hot water service, and iron pipes have been avoided. Occasionally in recent years trouble has been experienced where galvanized iron or steel pipes have been substituted and where the water has been heated very hot. This has been the case in Springfield, Mass., where rusty water troubles have occurred to an increasing extent during the last few years. It is to some extent the case in Boston.

Conversely, it is also a fact that in localities where the public water supplies are hard, galvanized iron and steel pipes have been satisfactorily used for hot water supplies instead of brass. This is true of London, where the water supply is hard, whereas in the cities of Middle England, where the water supplies are softer, such pipe is avoided.

SOFT WATERS TREATED WITH ALUM, BUT NOT OVERDOSED

It is to the waters of this class especially that the attention of engineers has been drawn during the last few years, not only because

of the seriousness of the rusty water troubles that have occurred, but because, as a result of them, there has been growing up a prejudice against the use of alum as a coagulant. It should be said at the outset that such an inference should not be too hastily drawn, but judgment should be reserved until the matter has been considered broadly in all its aspects.

One of the instances with which the writer is most familiar is that of the red water plague at Watertown, N. Y., that has occurred since the introduction of a mechanical filter in 1905. The supply of this city is taken from the Black River. The water is an especially difficult one to treat, partly because of its high color, partly because it contains organic matter resulting from the pollution of the river by the wastes of pulp mills and partly because of its relatively low and variable alkalinity. On account of the high color and the fluctuations in the amount of organic matter and alkalinity that suddenly occur without warning, it is necessary to apply rather large amounts of sulphate of alumina. The figures in Tables 2 and 3 will serve to give an idea of the character of the water treated and the amount of alum that has been used.

TABLE 2

Average Color and Alkalinity of the Raw and Filtered Water at Watertown, N. Y., and the Quantity of Alum Used

YEAR	COLOR		ALKALINITY		QUANTITY OF ALUM USED GRAINS PER GALLON
	Raw water	Filtered water	Raw water	Filtered water	
1905	69	10	39	19	2 07
1906	62	9	39	22	2 09
1907	69	6	28	12	2 53
1908	65	7	31	14	2 34
1909	67	8	30	12	2 23
1910	70	12	28	10	2 36

Not long after the filter was put into service, complaints arose throughout the city that many of the copper-lined water-closet tanks were giving out through corrosion along the seams. This appeared to be due in part to a slightly increased conductivity of the water resulting from the alum treatment, but also to the fact that the filtered water was much clearer than the raw river water that had been previously used; so that the tanks, instead of being covered with a thick layer of slime, as they had been, were cleaner and there was greater exposure of the metal to the circulating water, a condition favoring corrosion through galvanic action. At the same time it was

TABLE 3

Typical Analysis of Watertown Water

	PARTS PER MILLION	
	Raw water	Filtered water
Turbidity	5.00	0.00
Color	78.00	4.00
Nitrogen as albuminoid ammonia	0.204	0.126
Nitrogen as free ammonia	0.036	0.018
Nitrogen as nitrites	0.004	0.003
Nitrogen as nitrates	0.150	0.120
Oxygen consumed, five minutes	13.00	6.40
Total hardness	37.50	39.00
Alkalinity	33.00	15.00
Incrustants	4.50	24.00
Chlorine	0.50	0.50
Iron	1.10	0.30

also found that the hot water in many of the houses was becoming rusty—so much so that in various instances the water was too dirty to be used for bathing. This was not generally true throughout the city, but was noticed more in some places than in others, being especially troublesome in some houses of recent construction.

A study of the matter at this time showed that the water from the filter as it left the plant contained a very small amount of iron and that the cold water in the city contained very little more than at the filter, as the figures given in table 4 show.

TABLE 4

Average Quantities of Iron Found in the Raw Water, Filter Effluent and Tap Water at Watertown, N. Y., 1906-1910.

	PARTS PER MILLION		
	Raw water	Filter effluent	Tap water
1906	1.0	0.2	0.35
1907	0.8	0.2	0.30
1908	0.65	0.1	
1909	0.5	0.1	0.20
1910	0.5	0.05	0.15

Such an increase in the amount of iron in water passing through the city mains is not an unusual one.

TABLE 5

Comparison of Color of Cold and Hot Water at Watertown, N. Y.

		PARTS PER MILLION COLOR		FREE CO_2		IRON	
		Cold	Hot	Cold	Hot	Cold	Hot
1908							
May 19	Filter effluent..	2		9.2		0.1	
19	Woodruff House	3	85	7.0	8.0		
20	247 Paddock St	3	280	6.5	7.0		
21	137 Pleasant St	4	70	6.5	7.5		
July 24	141 Paddock St	13	35	6.0	6.0	0.6	0.7
24	214 Paddock St.	14	32	6.0	6.5	0.2	0.9
24	302TenEyck St	15	23	6.5	7.0	0.3	0.4
24	201 Arsenal St	18	22	6.5	7.0	0.3	0.4
24	154TenEyck St	19	23	7.5	8.0	0.2	0.3
24	38 Massey St	20	22	7.0	7.5	0.4	0.4
24	308 Huntington St	21	95	7.5	5.0	0.5	3.2

TABLE 6

Increase in Color of Watertown Water on Boiling

	COLD	AFTER BOILING
May 18, 1908		
Raw water	64	73
Filtered water, in laboratory	3	12
Filtered water	2	13
Tap water in the city, a	2	10
Tap water in the city, b	2	8
Tap water in the city, c	4	13
Tap water in the city, d	3	18

Further evidence that the corrosion of the city mains was not serious was obtained by flushing various hydrants throughout the city. The amount of rusty water drawn at such times was found to be not much greater than that normally observed.

When samples of hot water were compared with samples of cold water, however, it was found that in almost every case the hot water was more highly colored and contained more iron than the cold water. Thus, in May, 1908, hot water samples were found to have colors between 50 and 300, while, at the same time, the water as it left the filter plant and as it flowed from the cold water taps had a color of less than five. In some instances the iron came from the hot water faucets as flakes of rust, that would settle in a tumbler and cause a thick, reddish deposit on the bottom.

The red water plague was particularly severe during the winter of 1907–1908 at a time when the amount of alum used was rather large

and when the alkalinity of the filtered water was low. It should be noted here that the application of the alum to the water at the Watertown filter is watched with great care. The plant is in charge of a chemist and samples of raw and filtered water are collected and analyzed four times each day and have been ever since the plant was started. These analyses show that the filtered water has always been alkaline to methyl orange, or erythrosene. At times, when the alkalinity of the raw water has been low it has been necessary to use soda ash in order to provide alkalinity for the decomposition of the alum.

These same rusty hot water phenomena have been observed in many other places besides Watertown. The water supply obtained from the Passaic River at Little Falls and supplied to Paterson, Passaic, Montclair, and other places, has been the cause of more or less trouble of this character. Here also the water is relatively soft and somewhat colored, and is filtered through a mechanical filter, using alum as the coagulant. At Burlington, Vt., some complaints have been made of rusty hot water. The supply is taken from Lake Champlain and filtered through a mechanical filter, using alum as the coagulant. At Charleston, S. C., the red water plague has existed for a number of years and frequently has been serious. The supply is taken from a shallow storage reservoir on Goose Creek and filtered through a mechanical filter. The water is soft and lime is used as well as alum. Here the red water plague is said to have existed even before the use of alum.

A more recent instance of the red water plague is that which occurred at Springfield, Mass., in the spring of 1910. This trouble is said to have begun several years before this when the supply of the city was taken from the Ludlow reservoirs. It became somewhat more serious after the new supply from the Little River was put in service. This water passes through a sand filter before being delivered to the city. The raw water is rather high colored and, in order to reduce this, alum is used at times in connection with the filter. The water is extremely soft. Alum was applied to the water in small quantities between April 30 and May 18, 1910, and soda ash was applied between May 6 and May 15. Between May 18 and July 15 no coagulants were applied. During this time, even when no chemicals were being used, the rusty water troubles became serious and a detailed study of the matter was made by the Chief Engineer of the Waterworks Department, Mr. Elbert E. Lochridge, and the writer.

It was found that the trouble was worse in certain apartment

houses of recent construction, although a slight trouble was general throughout the city. The color of the hot water in the apartment houses varied all the way from 50 to 400, whereas the color of the cold water at the same time ranged from 25 to 45. The hot water also contained large amounts of rusty sediment which, on analysis, was found to be composed almost entirely of oxide of iron. Iron was also present in solution or as a colloid. This caused red stains of iron rust on white porcelain basins and in many cases made the water practically useless for all domestic purposes. Many complaints were made to the water department and the matter was the subject of much ill-feeling between tenants, janitors and landlords. In some instances it resulted in the loss of tenants. It caused pipes to become choked and in one case is said to have resulted in the bursting of a boiler. The figures in table 7 show the relative amounts of color, iron, alkalinity, free carbonic acid, dissolved oxygen, etc., in various samples of hot and cold water collected during the course of the investigation. Table 8 gives various data regarding the extent of the hot water troubles in various apartment houses, and the kind of heaters, tanks, piping, etc., used in supplying the hot water.

TABLE 7

Analysis of Hot and Cold Water at Springfield, Mass. Average Figures for Samples Collected Several Times Between June 4 and June 13, 1910

		RAW WATER	FILTER EFFLUENT	TAPS IN THE CITY			
				Nyasset Club	41 Spring St	103 William St.	88 Pearl St.
Color	Cold water	52	40	42	43	41	40
	Hot water			55	119	340	270
Iron	Cold water		0.25	0 26	0 20		
	Hot water			0.70	1 40		
Hardness	Cold water	10 9	11 50	12 30	12 30	12 5	13 5
	Hot water			12 90	12 60	12 0	13 5
Alkalinity	Cold water	8 9	8 20	10 40	9 80	9 6	8 5
	Hot water			12 80	13 00	12 9	11 0
Free CO_2	Cold water	1 9	3 10	2 20	2 50	4 9	2 5
	Hot water			0 70	1 30	3 0	2 5
Dissolved oxygen	Cold water	10 74	10 26			10 11	9 7
	Hot water					1 81	2 35
Temperature	Cold water	54 0	54 0			56 5	60 0
	Hot water					99 5	115 0

TABLE 8

Equipment for Supplying Hot Water to Various Apartment Houses at Springfield, Mass.

APARTMENT NO.	NUMBER OF FAMILIES	APPROXIMATE DATE OF CONSTRUCTION	HOT WATER EQUIPMENT			EXTENT OF HOT WATER TROUBLE
			Heater	Tank	Piping	
1	60	1902	Wrought iron	Insulated	Galvanized*	None
2	16	1903				None
3	8	1905	Cast iron	Galvanized	Brass and galvanized	None
4	8	1905	Cast iron	Galvanized	Brass and galvanized	None
5	50	1905	Cast iron		Galvanized	Slight
6	16	1906	Cast iron	Insulated	Galvanized*	None
7	16	1907				Slight
8	10	1908	Cast iron	Steel	Brass	Slight
9	12	1908	Cast iron	Steel	Galvanized	Bad
10		1908	Cast iron	Steel	Galvanized†	Very bad
11	8	1909	Cast iron	Steel	Galvanized†	Very bad
12	20	1909	Cast iron	Steel	Galvanized†	Bad
13	16	1909	Cast iron	Steel	Galvanized†	Very bad
14		1910	Cast iron	Steel	Galvanized	Bad

*Apparently good quality.
†Apparently poor quality.

The boilers used were generally made of cast iron, although in the case of one or two large installations steel boilers were found. The tanks were sometimes galvanized iron or steel, sometimes made of steel blackened on the outside and apparently with no protective coat on the inside. Their capacities varied from 100 to 500 gallons. In practically every case where trouble was observed the water passed through one of these unprotected steel tanks.

The pipes used for the conveyance of the hot water were found to be chiefly of galvanized steel. Possibly in some of the older installations they may have been galvanized iron, but this could not be told from inspection. In one instance brass pipe was found in connection with a steel tank. In some of the private houses examined the hot water piping was of brass and lead and the boilers of copper. The quality of the galvanized pipe used differed considerably in different buildings. In some cases, especially the older installations, the pipe appeared to be of much better character than in the houses more recently built, the amount of zinc on the pipe being greater and the coating smoother. These pipes of better grade were almost invariably found in connection with galvanized tanks or with tanks covered with packing. The poorer qualities of galvanized pipe were

usually found associated with the unprotected steel tanks, this being apparently a cheaper installation.

When it was found that the rusty water troubles were associated with the steel tanks and galvanized pipes of poor quality, an investigation was made to ascertain the character of the inside of some of the galvanized piping used in Springfield. Samples were obtained from various plumbers and dealers, from the stock of pipe in the water works yard, and from pipes used in other cities. These samples were sawn asunder so as to expose the interior. The results, taken as a whole, showed extremely bad conditions. Scarcely a single specimen of a perfect pipe was obtained. In some cases there were large areas of the interior of the pipe entirely uncoated with zinc, and where the steel was exposed and coated with rust; others were spotted with pieces of mill scale embedded in the zinc coating; others were rough from the presence of dross from the spelter bath; sometimes a line was found along the seam where the coating had not adhered to the pipe, possibly on account of the failure of the acid to remove the mill scale during process of galvanizing. In several pipes where the coating was good, as far as the eye could see, microscopical and chemical tests showed the presence of pin holes where rusting might occur. In some instances a poor coating of zinc on the inside was accompanied by a poor appearance of the outside coating, but the samples as a whole showed that it was not always possible to tell the nature of the inside of the pipe from the appearance of the outside. A number of samples of galvanized pipe obtained from different dealers and plumbers, from the water department stock and elsewhere, were carefully examined on both the outside and inside, the specimens being sawn in two for that purpose. The physical appearance of the coatings was first recorded, after which the specimens were examined with the microscope and tested for porosity by means of Walker's test and by the use of ferri-cyanide.

Walker's test was made as follows: The raw edges of the metal and bare spots were first coated with asphalt in order to protect them and then the specimens were placed in a solution of boiling caustic potash. If any metal remained exposed and in contact with the zinc, bubbles of hydrogen gas were generated and could be easily seen with the eye. In the case of many specimens this test was not necessary, as the bare, uncoated spots could be easily detected without it, but in other specimens, which to the eye appeared to be thoroughly coated, this test revealed the presence of pin holes. These might become foci of corrosion, and the beginning of tubercle

formation. As corrosion proceeded such tiny bare spots would increase in size until finally a large area was exposed. No specimen was examined that did not show at least one or two such pin holes. The character of the coating on the outside did not always indicate the character of the coating on the inside, that is to say, a good exterior did not necessarily mean a good interior. A bad exterior, however, was invariably accompanied by a bad interior.

WATERS OVERDOSED WITH ALUM

It sometimes happens with mechanical filter plants that more alum is used than can be decomposed by the alkalinity naturally present in the water. When this occurs the filtered water becomes acid and its corrosive powers are greatly increased. Such waters are liable to be the cause of the rusting of iron and steel pipes, tanks, etc., with both cold and hot water. Instances of this kind have not infrequently come to the attention of the writer. One of these was at Athol, Mass., where the supply was taken from a small reservoir and was treated with alum and filtered through a pressure filter before passing to the city. On account of irregular application of the chemical, the filtered water was intermittently acid.

Another instance was the supply of Durham, N. C., where a similar condition prevailed.

Other and very common instances of this overdosing have occurred in New York City and elsewhere, in connection with the use of small house filters where alum is used as a coagulant. These filters are widely use by hotels and apartment houses of the better class. They are commonly provided with a device for applying alum to the water before filtration. Usually the alum control is very imperfect at best and very poorly looked after, and the result is that the water is not infrequently overcharged with alum.

MECHANICAL FILTRATION WITHOUT RED WATER TROUBLES

In order to correct any misapprehension in regard to mechanical filtration, it should be stated that mechanical filters with alum used as a coagulant have been in service for many years in many cities of this country, without being the cause of any red water plague. But where this is the case the waters are relatively hard and the filtered water has a considerable residual alkalinity. The writer has corresponded with many engineers and chemists in various cities where

mechanical filters have been used, and the dividing line between those which have caused trouble and those which have not, appears to be sharply drawn according to the hardness of the water, that is to say, the use of alum with hard water causes no trouble, whereas the use of alum with soft water may cause serious trouble.

WATERS NATURALLY CHARGED WITH IRON

Many public water supplies contain excessive amounts of iron and with these rusty water is common, both cold and hot. At Far Rockaway, N. Y., Redbank, N. J., Superior, Wis., Reading, Mass., and elsewhere, filter plants have been constructed for removing iron. Methods of deferrization have been well described by Weston (*Trans. Am. Soc. C. E.*, vol. 64, September, 1909).

SEASONAL OCCURRENCE

It is difficult to state any particular time of the year when the red water troubles are at their maximum, but generally speaking, so far as the observation of the writer has gone, the fall and winter months are the worst. This appears to be due in part to the fact that during the winter the hot water is maintained at a higher temperature and for more hours in the day than during the summer, when it is not uncommon to allow the range fire to go out at night. In winter also surface waters contain more dissolved oxygen. Another, and perhaps a more important cause, is the fact that organic matter freshly dissolved in water appears to be more corrosive than organic matter that has passed through various stages of fermentation. This is referred to later in the paper. The seasonal distribution of coloring matter in water differs in different localities. An increase in color usually occurs during the late fall and early winter, after the leaves have fallen. The maximum color, however, is more commonly observed during the months of May and June, after the spring rains have caused the swamp lands to discharge their waters. In some instances it is said that the hot water is more rusty at the time of this maximum color of the early summer. In other cases, the winter maximum of color, caused by freshly dissolved organic matter, gives rise to the worst conditions.

EFFECT OF ALGAE

Algae may influence the corrosive property of water indirectly by reducing the amount of carbonic acid present. These microscopic

organisms in their photo-synthetic processes consume carbonic acid and liberate oxygen. Some of them even have the power of taking carbonic acid from the bicarbonates of calcium and magnesium, leaving the water alkaline. In some reservoirs and lakes where algae flourish, this is a common phenomenon, the water being alkaline during the summer season but acid to phenolphthalein during the spring and fall or even during the winter. Where these conditions prevail, the water would naturally be less corrosive during the summer than at other times. If such a water were filtered, using alum, this protective action of the algae would be lost during the summer. On the other hand, it must be remembered that the growth of algae tends to increase the amount of oxygen in the water and waters may be temporarily super-saturated with oxygen from this cause. This is not of material importance if the water used is taken from a layer in circulation and therefore in contact with the air, but it may be a matter of some moment if the water is taken from a point below the region of circulating water, i.e., from below the thermocline This phase of the subject has not been thus far investigated but it offers an interesting and promising field of study.

LOCALIZATION OF RED WATER TROUBLES

Wherever the red water plague has been observed a most conspicuous phenomenon has been that the rusty hot water has not been general throughout the city but has differed greatly in different houses. Often many houses are practically exempt, while neighboring houses may be seriously affected. This was conspicuously true in one instance in Springfield, Mass., where there were two apartment houses on the same street taking water from the same mains under identically the same conditions and with the plumbing arranged substantially the same way. In one of these apartment houses no trouble was experienced, while in the other the conditions were very bad. The only noticeable difference between these two buildings appeared to be in the character of the material used for the construction of the heaters, tanks and piping used for the hot water services.

If one were to generalize, it may be said that it has usually been found that houses recently built have suffered more severely than older houses; that houses in which brass pipe and copper boilers have been used have suffered little or none at all; that houses in which galvanized wrought iron and steel pipe have been used have been the

ones affected and those in which the piping has been apparently of poor quality have suffered the worst. The troubles have been somewhat more marked in buildings where the circulating pressure system is used than in those where the tank system is used, but exceptions have been found, as, for instance, in tall buildings. Temperature is a very important factor. The hotter the water the more the trouble. In short, the physical conditions that appear to favor the formation of iron rust in hot water are higher pressure, higher temperature, and greater circulation.

In any particular house, differences are noticed in different parts. The water supplied to the lower floors of high buildings is often slightly more discolored than the water supplied to the upper floors, but this difference is not always noticed. When pipes are examined the greatest amount of rust is found where the circulation of the water is most rapid. More is found in horizontal than in vertical pipes. Sometimes the pipes between the heater and the storage tank are very nearly, if not completely, choked with rust. Here the circulation is naturally very rapid.

TEMPORARY RUSTINESS

It is a matter of common occurrence to find the first water drawn from a hot water faucet to be somewhat rusty, the water afterwards running clear. This may happen even in places where there is no general red water problem. It is especially likely to happen when the water contains such electrolytes as sodium chloride. It is due to galvanic action between different metals. Thus, where brass faucets have been attached to steel pipes the writer has found the first tumblerful of water drawn to be rusty and the water afterwards drawn to be clear. This temporary rustiness is often a conspicuous phenomenon where gas heaters are employed and is apparently due to the use of different metals in places where the temperature of the water is high.

SOFT WATERS MORE CORROSIVE THAN HARD WATERS

The fact that very soft waters are more corrosive than hard waters was illustrated by the following laboratory experiment. Four flasks containing distilled water, Brooklyn tap water, and mixtures of the two, were fitted with return condensers and boiled for six hours. Into them had been placed strips of Russia iron of equal size, but before they were introduced the water had been boiled to

remove any carbonic acid. After boiling, the strips of iron were removed and the amount of iron dissolved in the water determined by analysis. The results of the analysis are given in table 9.

TABLE 9

Effect of Alkalinity of Water on Corrosion of Iron.

EXPERIMENT NUMBER	WATER USED	ALKALINITY OF WATER	IRON DISSOLVED PARTS PER MILLION
1	Distilled water	0	3.6
2	Brooklyn tap water	19.5	1.2
	Brooklyn tap water, diluted with distilled water	10.0	2.4
	Brooklyn tap water, diluted with distilled water	5.0	3.6
3	Brooklyn tap water	20.0	2.7
	Brooklyn tap water, treated with 1 grain per gallon of alum	13.0	3.2
	Brooklyn tap water, treated with 2 grains per gallon of alum	7.0	6.4

It was found that the distilled water had dissolved three times as much iron as the Brooklyn tap water, but that a sample of Brooklyn tap water diluted with distilled water until its alkalinity was only five parts per million dissolved as much as the distilled water itself. Experiments with other waters gave similar results. Waters of different alkalinities obtained by adding different amounts of alum to Brooklyn tap water and filtering were treated in a similar way, and it was found that the water that had its alkalinity reduced to seven parts per million dissolved 2.3 times as much iron as the untreated Brooklyn tap water which had an alkalinity of 20 parts per million.

ROLE OF CARBONIC ACID

Carbonic acid dissolved in water increases the hydrogen ions present and therefore increases its corrosive properties. This is a fact too well known to require proof. Carbonic acid is present to some extent in nearly all natural waters. In swampy waters it is high and in many well waters it is very high. The use of alum in water increases the carbonic acid and therefore tends to increase its corrosive properties. Carbonic acid is very soluble in water. It is driven off by heat, but not when under the pressure existing in city mains. Carbonic acid in hot water in the presence of the carbonates of the alkaline earths does not appear to have the corrosive properties that it has in soft waters.

RÔLE OF ORGANIC ACIDS

Very little is known chemically about the effect of organic acids in the corrosion of iron. It has been generally considered that swampy waters owe their corrosive properties in part to humic acid or similar organic substances. Such waters nearly always contain carbonic acid and some chemists have recently claimed that the corrosive properties are due to this carbonic acid rather than to the organic acids themselves. There is reason to believe, however, that the organic acids play a considerable part, especially in the case of fresh extracts.

DIFFERENCE BETWEEN FRESH AND OLD EXTRACTS OF ORGANIC COLORING MATTER

In the course of various experiments on decolorization, marked differences have been found between fresh and old extracts of coloring matter. It is a well known fact that the hue of colored waters varies at different seasons and that fresh extracts of leaves and recent vegetations have a greenish hue, while the older extracts of peat found in the swamps have a reddish hue. This appears to be due to the state of oxidation of the iron present.

Analyses have shown that old and new extracts of the same color differ materially with respect to the amount of organic matter present.

TABLE 10

Analysis of Fresh and Old Extract of Leaves

	PARTS PER MILLION	
	Fresh extract	Old extract
Color	50	50
Nitrogen as albuminoid ammonia	0.368	0.052
Nitrogen as free ammonia	0.170	0.094
Oxygen consumed	28.0	11.0
Iron	0	0.100
Acidity with phenolphthalein, cold	7.0	3.0
Acidity with phenolphthalein, after neutralizing and boiling 5 minutes	1 700	0

When the samples were heated the following changes in color took place.

	COLOR	
	Fresh extract	Old extract
Original color	50	50
After bringing to a boil	68	50
After boiling five minutes	85	66

The addition of various reagents added in equal quantities affected the extracts differently, as shown by the following figures.

	FRESH EXTRACT	OLD EXTRACT
Sodium hydrate	280	74
Calcium hydrate	260	74
Sodium carbonate	240	74
Hydrochloric acid	38	38
Calcium sulphate (not sufficient to decolorize)	110	55

Even the physical appearance of the extracts differed. When allowed to stand a deposit formed in the old extract and the supernatant liquid was nearly clear, whereas in the case of the fresh extract less deposit formed and more organic matter was present in a colloidal state.

The old extract was decolorized with alum very much more readily and with the use of less chemical than the fresh extract. The reduction in alkalinity for each grain per gallon of alum used was less in the case of the fresh extract (Table 11).

It is a well known fact that acids tend to reduce the color of water, while alkalis tend to increase it. This is illustrated by the figures in Table 12.

ACTION OF SULPHATE OF ALUMINA

When sulphate of alumina is added to water that contains calcium carbonate, the following reaction takes place.

$$Al_2(SO_4)_3 . 18\ H_2O + 3\ CaCO_3 . CO_2 + 3\ H_2O = 3\ Ca\ SO_4 + Al_2(OH)_6 + 6\ CO_2$$

The products of the reaction are aluminum hydrate, which is the coagulant desired, calcium sulphate, which remains in solution, and carbonic acid gas, which also remains in solution. When the amount of calcium carbonate present is relatively large, this reaction takes place quickly, but when the alkalinity is low the reaction appears to take place more slowly. This has been shown by various con-

TABLE 11

Relation between the Amount of Sulphate of Alumina Required to Decolorize Colored Waters made from Old and Fresh Extracts of Leaves, and the Reduction of Alkalinity

LEAF EXTRACT	ORIGINAL COLOR	FINAL COLOR	GRAINS PER GALLON OF ALUM	PARTS PER MILLION		
				ORIGINAL ALKALINITY	FINAL ALKALINITY	REDUCTION IN ALKALINITY FOR EACH GRAIN PER GALLON OF ALUM USED
Old	25	4	1	15.5	7.5	8.0
Fresh	25	10	1	15.0	7.0	8.0
Old	25	2	2	15.5	2.0	6.8
Fresh	25	8	2	15.5	2.0	6.5
Old	50	3	1	16.5	8.0	8.5
Fresh	50	65	1	15.5	9.0	6.5
Old	50	2	2	16.5	2.0	7.3
Fresh	50	13	2	15.5	2.5	6.5
Old	75	6	1	17.0	9.0	8.0
Fresh	75	70	1	16.5	10.0	6.5
Old	75	5	2	17.0	0.5	8.3
Fresh	75	14	2	16.5	1.5	7.5
Old	100	80	1	17.0	11.0	6.0
Fresh	100	165	1	15.0	11.5	3.5
Old	100	2	2	17.0	1.5	7.8
Fresh	100	20	2	15.0	3.0	6.0

TABLE 12

Color of Extracts of Chestnut Leaves Obtained with Distilled Water Containing Various Salts in Solution after Standing Ten Days

	PARTS PER MILLION	COLOR PRODUCED BY 0.5 GRAM OF LEAVES IN 300 CC. OF WATER
Distilled water		500
Calcium carbonate	50	1100
Calcium carbonate	100	1100
Magnesium carbonate	50	900
Magnesium carbonate	100	1100
Barium carbonate	50	500
Barium carbonate	100	500
Calcium sulphate	50	500
Calcium sulphate	100	420
Magnesium sulphate	50	590
Magnesium sulphate	100	490
Sodium hydrate	50	900
Sodium hydrate	100	1000
Sodium chloride	50	340
Sodium chloride	100	460

ductivity experiments made for the writer by Mr. Melville C. Whipple. This is in line with the well-known laws of mass action.

The change of calcium carbonate to calcium sulphate is expressed in the chemical analysis by a reduction in the alkalinity of the water. Theoretically, this amounts to 7.7 parts per million for each grain per gallon of alum added to the water. The increase in the amount of free carbonic acid amounts to 6.8 parts per million for each grain per gallon of alum, assuming the original alkalinity to be in the form of bi-carbonate. Laboratory experiments made with pure chemicals show reductions in alkalinity that correspond to the theoretical amounts. In practice, however, it has been frequently noticed that the reduction in alkalinity is somewhat less than the theoretical. Fuller found this to be true with the turbid waters of the Ohio River and explained it as being due to the absorption of a certain amount of the sulphate of alumina by the clay. The writer has found it to be the case with colored waters and especially with soft colored waters. This is shown by the figures in Table 13. It is possible that here also it may be explained by the absorption of the alum by the colloidal organic matter present in the colored water, but as it occurs also with waters that have been filtered and the suspended matter removed, it is perhaps more reasonable to believe that some of the alum unites chemically with the organic matter. The higher the color of the water, the larger the amount of aluminum sulphate that is combined in this way. It was found that when the amount of alum added was insufficient to coagulate and precipitate the coloring matter, the reduction in alkalinity was very low.

From the observations and experiments it seems reasonable to believe that with colored waters a double reaction takes place and that a small part of the alum unites with the organic matter directly, while the larger part reacts with the calcium carbonate in the manner above mentioned. The nature of this aluminum organic compound is not known. Possibly it exists as a colloid.

Another theory of the action of alum on soft waters is that the reaction does not take place exactly as above indicated, but that instead of all the alum being changed to hydrate some of it forms a basic sulphate of alumina which would be somewhat soluble and might conceivably pass through a filter. Fay, in his recent work on *Coal Tar Dyes*, states that this is the case when sodium carbonate is used to decompose the alum. Jenning's experiments at Watertown are also interesting in this connection (Table 14).

TABLE 13

Relation between Decolorization of Soft Water with Sulphate of Alumina and Reduction of Alkalinity

Experiment number	Original color	Final color	Grains per gallon of alum used	Parts per million: Original alkalinity	Parts per million: Final alkalinity	Parts per million: Reduction in alkalinity for each grain per gallon of alum
	25	25	0	17.0	17.0	0
1	25	2	1	17.0	9.5	6.5
	25	0	2	17.0	3.0	7.0
	50	50	0	17.5	17.5	0
2	50	48	0.5	17.5	14.2	6.6
	50	6	1.0	17.5	10.2	7.3
	50	50	0	17.0	17.0	0
3	50	5	1	17.0	10.8	6.2
	50	2	2	17.0	4.5	6.3
	75	75	0	18.5	18.5	0
4	75	10	1	18.5	12.5	6.0
	75	5	2	18.5	5.0	6.8
	75	75	0	16.5	16.5	0
5	75	14	1	16.5	11.5	5.0
	75	2	2	16.5	4.5	6.0
	100	100	0	18.0	18.0	0
6	100	32	1	18.0	12.2	5.8
	100	11	1.5	18.0	7.2	7.2
	100	100	0	18.5	18.5	0
7	100	30	1	18.5	12.0	6.5
	100	4	2	18.5	4.8	6.8
	100	100	0	18.0	18.0	0
8	100	78	1	18.0	14.0	4.0
	100	5	2	18.0	6.0	6.0
	100	100	0	20.0	20.0	0
9	100	90	1	20.0	18.5	1.5
	100	10	2	20.0	6.0	7.0

TABLE 14

Effect of the Use of Sodium Carbonate with a Soft Water on the Reduction of Alkalinity by Sulphate of Alumina. (Experiment by F. H. Jennings, June 7, 1910. Two grains per gallon of alum added to Watertown raw water, with and without soda ash).

	Reduction in alkalinity for each grain per gallon of alum	
	No soda ash used	Ten parts per million of soda ash used
One and one-half hours after adding alum	5.88	5.88
Twenty-four hours after adding alum	5.88	6.42

It is possible, also, that where the amount of alkalinity in the raw water is very low the alum reaction does not go to completion but a certain small amount of aluminum sulphate remains in the water. Conductivity experiments made by Melville C. Whipple have shown that whereas the conductivity of hard water is increased by a very small amount when alum is added, the conductivity of a relatively soft water is considerably increased by the addition of the same amount of alum. Thus, in one series of experiments, in which one grain per gallon of alum was added to solutions of calcium carbonate of different strengths, it was found that the increase in conductivity in the solution containing 100 parts per million of calcium carbonate was only about 2 per cent, whereas in the solution containing 50 parts per million it was 15 per cent; in the solution containing 25 parts per million, 20 per cent; and in the solution containing 10 parts per million, 35 per cent.

When the amount of calcium and magnesium carbonate naturally present in the water is insufficient to decompose the alum added, alkalinity may be provided by the use of sodium carbonate, lime or even sodium hydrate. The use of the latter is somewhat troublesome. Soda ash has some advantages, but experience has shown that at Watertown it did not prevent the rusty water conditions. In the reaction of alum and sodium carbonate the reduction of alkalinity is theoretically 8.1 parts per million for each grain per gallon of alum, and the amount of carbonic acid added to the water is only 3.4 parts per million. In the reaction with lime the alum adds no carbonic acid to the water, but the hardness is increased by 7.7 parts per million for each grain per gallon of alum added.

TABLE 15

Effect of Coloring Matter in Water on Reduction of Alkalinity. Experiments made by adding 0.75 grains per gallon to distilled water to which calcium carbonate had been added to give the desired alkalinity, and extract of leaves to give the desired color.

COLOR	REDUCTION OF ALKALINITY FOR EACH GRAIN PER GALLON OF SULPHATE OF ALUMINA	
	Alkalinity	Alkalinity
	10	75
0	6.6	8.0
50	5.3	6.6

ALUM COMPOUNDS IN THE FILTERED WATER

Under ideal conditions, all of the alum added to the water before filtration is decomposed and takes the form of aluminum hydrate, which is removed by the filter. Under some unfavorable conditions, however, aluminum compounds may conceivably persist in the filtered water even though no alum, as such, remains. If the filter is not working properly some of the hydrate of alumina may pass through the sand. If present in large amounts this would produce a slight turbidity or opalescence in the water. If present in very small amounts it might give to the water merely a bluish cast. It is believed by some physicists that the natural blue color of large bodies of water is due to the presence of aluminum compounds.

If the alum reaction should not be complete, but if a small amount of basic sulphate should be formed, it is possible that this might remain as such dissolved in the filtered water. The alum commonly used for filtration purposes is "basic," that is, it contains a larger amount of aluminum than that theoretically required to combine with the sulphuric acid. It is possible that a part, at least, of this excess is present in the form of basic sulphate and not as aluminum hydrate. The hydrate is insoluble in water but it is frequently noticed in the analysis of alums that the excess of aluminum compounds is greater than the insoluble matter.

Finally, if there is a chemical combination between the aluminum sulphate and the organic matter, it is possible that this compound might pass through the filter either in the form of a colorless solution or as a colloid.

In the case of an overdosed water, aluminum sulphate itself, that is, undecomposed alum, is present in the filtered water.

EFFECT OF HEAT ON ALUM-TREATED WATER

If the filtered water should contain basic aluminum sulphate it is reasonable to believe that heating it would tend to complete the reaction so that aluminum hydrate would be precipitated in the hot water. If the filtered water contained aluminum sulphate in combination with organic matter, heating might decompose it and this also would tend to throw down the aluminum hydrate in the hot water. In this connection it is worthy of note that in Watertown analyses of the deposits in the hot water pipes have shown considerable quantities of aluminum, sometimes as high as 7 per cent.

These changes in the basic sulphates and combinations of alum with organic matter would naturally tend to increase the hydrogen ions and therefore the corrosive properties of the water.

Experiments have shown that when alum is so added to waters that the alkalinity of the filtered water is reduced to 5 or 8 parts per million, the filtered water, after long boiling, has an acid reaction when tested with the phenolphthalein indicator, whereas the reaction is alkaline if the residual alkalinity of filtered water as shown by the ordinary methyl orange or erythrosene test is kept higher than 5 or 8 parts per million. Many experiments along this line have been made by the writer and the results are shown in fig. 6.

From a smooth curve drawn through these results it would appear that when the alkalinity of the filtered water falls below six parts per million the water will commonly have an acid reaction with phenolphthalein after boiling. This acidity of the hot water is apparently not due to carbonic acid.

TABLE 16

Reaction of Hot Alum-Treated Water. Table showing the effect of Sulphate of Alumina on the Reaction of Soft Waters

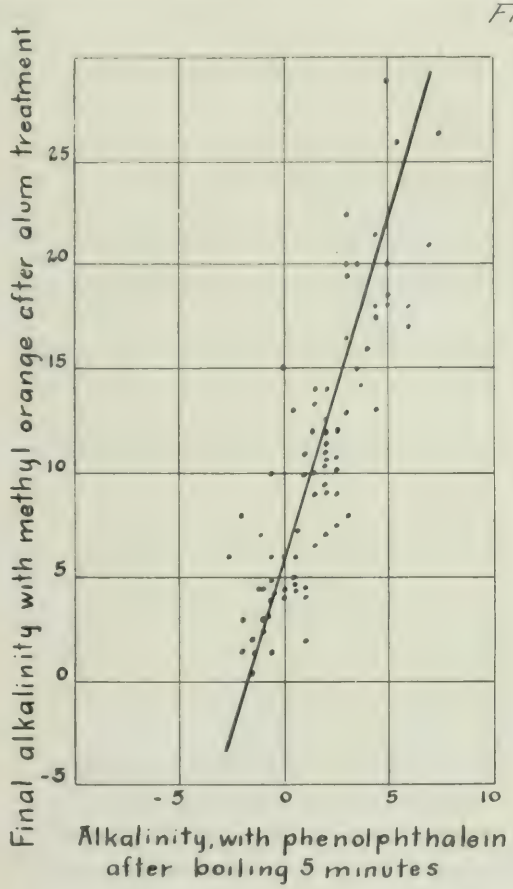
ORIGINAL ALKALINITY OF THE WATER DETERMINED IN THE COLD USING METHYL ORANGE OR ERYTHROSENE	ALKALINITY OF THE TREATED WATER* DETERMINED IN THE COLD USING METHYL ORANGE OR ERYTHROSENE	ALKALINITY OF THE TREATED WATER DETERMINED AFTER BOILING FIVE MINUTES USING PHENOLPHTALEIN
40	25	5.8
35	20	4.3
30	15	2.7
25	10	1.2
21	6	0.0
20	5	-0.3 (acid)
15	0	-1.8 (acid)
10	-5 (acid)	

*Two grains of sulphate of alumina per gallon.

Some of the samples of filtered water obtained from Watertown, Little Falls, and elsewhere, in which the residual alkalinity was low, were found to be acid with phenolphthalein after boiling off the carbonic acid.

In a series of experiments made to determine the relative corrosive effects of alum-treated waters in which the residual alkalinity varied, it was found that when the residual alkalinity fell much below 10 parts per million the corrosive effect of the water on iron increased materially.

Fig 6



ACID CONDITION OF SOFT WATER TREATED WITH ALUM AFTER BOILING FOR 5 MINUTES

When waters that contain calcium carbonate are boiled a dissociation takes place, with the formation of the ($O\overline{H}$) ion. These tend to neutralize the hydrogen ions and thus prevent corrosion.

Whatever may be the explanation, and the chemistry of the subject is by no means clear, the fact appears to be well established that as a result of the application of sulphate of alumina to soft, colored waters a corrosive property is imparted that acts when the water is heated, but that is insignificant as long as the water remains cold.

OXYGEN CONDITIONS

The theory of corrosion and rusting requires not only the presence of the hydrogen ion, but the presence of oxygen. It has been well proved that where the hydrogen ion is present the rusting of iron is proportionate to the concentration of the oxygen. The greater the amount of oxygen, therefore, the greater the rusting. Generally speaking, hot water contains more than enough oxygen to oxidize the iron dissolved and it is probable that the increased corrosion attending increased amounts of dissolved oxygen is due to its action as a depolarizer.

Surface waters used for public supplies usually contain oxygen up to their saturation point. The solubility of oxygen decreases as the temperature rises. Near the freezing point water will hold in solution about twice as much oxygen as at summer temperatures. The solubility decreases according to a regular curve and at the boiling point becomes nil.

The solubility of oxygen is also affected by pressure and increases directly with it. Water under a pressure of two atmospheres will hold twice as much oxygen as water under a pressure of one atmosphere. The solubility of oxygen in water at different temperatures and pressures is shown in Table 17 and fig. 7. When water saturated with oxygen is heated, the pressure remaining the same, oxygen gas is liberated. This is also true of the dissolved nitrogen. When a glass of cold water is allowed to stand in a warm room, bubbles of air may be seen collecting on the glass. In order for super-saturation to occur when water is under pressure it is necessary to raise the temperature considerably and the greater the pressure the higher must the temperature be raised. For example, water just above the freezing point contains 14.5 parts per million of dissolved oxygen. If placed under a pressure of 40 pounds per square inch it would be necessary to raise the temperature to 135° F. in order for super-

TABLE 17

Table showing the Solubility of Dissolved Oxygen in Distilled Water at Different Temperatures and Pressures

TEMPERATURE		WATER PRESSURE IN POUNDS PER SQUARE INCH					
		0	20	40	60	80	100
C°	F°	PRESSURE IN FEET OF WATER					
		0	46.2	92.4	138.6	184.8	231.0
0	32.0	14.7	34.7	54.7	74.7	94.7	114.7
1	33.8	14.28	33.7	53.1	72.6	92.0	111.3
2	35.6	13.88	32.8	51.6	70.6	89.4	108.1
3	37.4	13.50	31.9	50.3	68.7	87.0	105.2
4	39.2	13.14	31.0	49.0	66.8	84.7	102.6
5	41.0	12.80	30.2	47.7	65.1	82.5	99.9
6	42.8	12.47	29.4	46.4	62.4	80.3	97.2
7	44.6	12.16	28.7	45.3	61.8	78.2	94.8
8	46.4	11.86	28.0	44.2	60.3	76.3	92.5
9	48.2	11.58	27.3	43.2	58.8	74.6	90.2
10	50.0	11.31	26.7	42.2	57.5	73.0	88.1
11	51.8	11.05	26.1	41.2	56.2	71.3	86.1
12	53.6	10.80	25.5	40.3	54.9	69.6	84.2
13	55.4	10.57	24.9	39.4	53.7	68.0	82.3
14	57.2	10.35	24.4	38.5	52.6	66.6	80.6
15	59.0	10.14	23.9	37.8	51.6	64.5	79.0
16	60.8	9.94	23.4	37.1	50.6	64.0	77.5
17	62.6	9.75	23.0	36.4	49.6	62.8	76.0
18	64.4	9.56	22.6	35.7	48.6	61.6	74.6
19	66.2	9.37	22.2	34.9	47.7	60.4	73.1
20	68.0	9.19	21.7	34.2	46.8	59.2	71.7
25	77.0	8.35	19.7	31.1	42.4	53.8	65.1
30	86.0	7.60	17.9	28.3	38.6	48.9	59.2
35	95.0	6.90	16.3	25.7	35.1	44.4	53.8
40	104.0	6.18	14.6	23.1	31.4	39.8	48.2
45	113.0	5.50	13.0	20.5	27.9	35.5	42.8
50	122.0	4.82	11.4	17.9	24.5	31.1	37.6
55	131.0	4.18	9.9	15.6	21.3	26.9	32.6
60	140.0	3.56	8.4	13.3	18.1	22.9	27.7
65	149.0	3.00	7.1	11.2	15.3	19.3	23.4
70	158.0	2.50	5.9	9.3	12.7	16.1	19.5
75	167.0	2.05	4.8	7.6	10.4	13.2	16.0
80	176.0	1.65	3.9	6.2	8.4	10.7	12.9
85	185.0	1.30	3.1	4.8	6.6	8.4	10.1
90	194.0	0.95	2.2	3.5	4.8	6.1	7.4
100	212.0	0.					

saturation to occur, and if the pressure were 100 pounds per square inch it would be necessary to raise the temperature to 170° F. When heated above the saturation point, a portion of the air will go out of

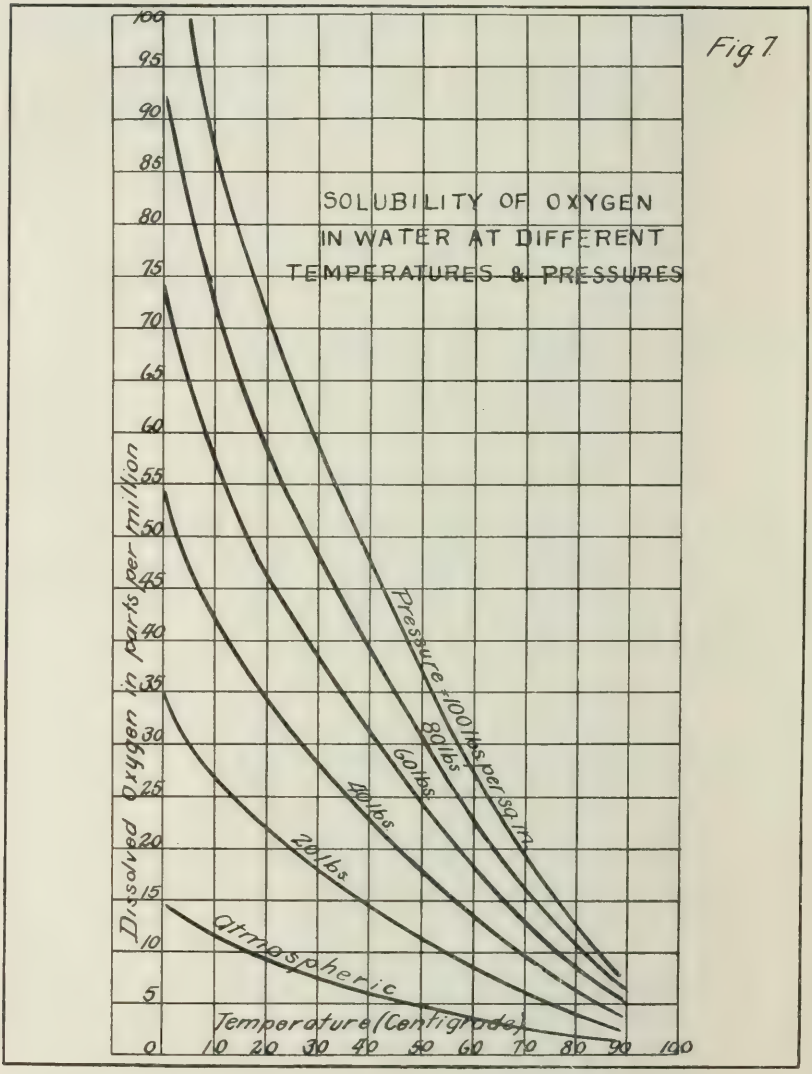

SOLUBILITY OF OXYGEN
IN WATER AT DIFFERENT
TEMPERATURES & PRESSURES
Dissolved Oxygen in parts per million
Temperature (Centigrade)
Pressure = 100 lbs per sq. in.
80 lbs
60 lbs
40 lbs
20 lbs
Atmospheric
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
10 20 30 40 50 60 70 80 90 100

Fig 7

solution. This occurs to some extent in domestic hot water systems. The rumbling of kitchen boilers is a common phenomenon in houses where the tank system is used and the pressure is low. The liberated air ultimately finds relief through the expansion pipe or the opened taps. It has been commonly noticed in feed water heaters that the corrosion increases with the temperature of the water up to a certain point, which is somewhat between 170° and 190° F., and above that decreases.

Woolson (*loc. cit.*) has described an experiment made by him showing that heat increases electrolytic action. He says:

> A small galvanic cell was made by immersing strips of sheet steel and zinc in Croton water, the cell being connected to a millivolt galvanometer. It was found that heating the water increased the current obtained. The gain was gradual up to about 180 or 190° F., when the accumulation of air bubbles upon the plates seemed to arrest electrolytic action.

Similar experiments with the same results have been made in Germany.

Some ground waters contain little dissolved oxygen and these waters do not seriously rust the pipes.

Galvanized iron or steel pipes are largely used in connection with the heating of houses by the hot water system. These pipes do not often corrode seriously, an obvious reason being that the water is used over and over and the oxygen becomes used up and its power of rusting brought to an end.

EFFECT OF CIRCULATION

Experience has shown that the more rapid the circulation of water through a hot water system the greater is the rusting of the pipes. The circulation of the water prevents the accumulation of hydrogen on the metallic iron, that is, prevents polarization. This, together with the mechanical removal of the oxidized iron, tends to increase the corrosion. The growing tendency to use the circulating system may in part explain why the rust problem is more serious now than formerly. Allusion has already been made to the fact that the circulating pipes between the heaters and boilers often become completely choked with rust when the rest of the system is much less affected.

ACTION OF SOFTENED WATERS ON GALVANIZED PIPE

It has been found at St Louis, Columbus, and other cities where water has been softened by the use of lime, or where lime has been used in connection with copperas as a coagulant, that the treated water contains normal carbonates. It acts on the zinc coating of pipe, dissolves the zinc as a zinc carbonate and thus exposes the metallic iron to the water. It has been found even that such water will remove zinc from an alloy, and meters and other fixtures have suffered in consequence. Such waters do not naturally corrode iron; but if, after the service pipe has become thus exposed, there should be a change in the character of the water, so that there were no longer an excess of hydroxyl ions, the rusty water problems would probably become a serious matter.

IRON AND STEEL PIPE

There seems to be abundant reason to believe that the character of the iron and steel pipe used has a most important influence on the rusty water problem. In Springfield the inspections of the apartment houses plainly indicated that the worst red water conditions existed in the buildings of cheaper construction where unprotected steel tanks were used for storing the hot water and galvanized steel pipes were used for its distribution. Some of the piping that was examined was found to be deeply pitted and the pipes completely choked with iron rust. Examination was made of some of these pipes. They were found, for the most part, to be made of steel and very badly galvanized. The pipes of better grade appeared to be less corroded. Woolson, in his study of the New York bathing houses, found that in the pipe lines wrought iron and steel were indiscriminately used. Both were more or less corroded.

Laboratory experiments that have been made by various authorities have shown relatively little difference in the corrosion of wrought iron and steel pipes. Where tests have been made by immersing samples in strongly acid solutions, steel pipes have sometimes given slightly better results than wrought iron pipes, and sometimes not as good. The laboratory data on this point are inconclusive. On the other hand, it seems to be common experience, and it is certainly the prevailing idea among engineers that so far as corrosion by water is concerned, wrought iron pipes stand better than steel pipes. Whether this is due to inherent differences between the two metals

or to more frequent imperfections in the manufacture of steel is something that cannot be readily determined from the data at hand. Homogeneity is an important element in the prevention of corrosion, and it is apparently possible for steel pipe to suffer more in this respect than pipe of wrought iron. So far as practical experience goes, most engineers believe it to be true that the best results are obtained by using the best grades of wrought iron; yet there is reason to believe that the better grades of steel pipe are more satisfactory than the poorer grades of wrought iron. Sufficient scientific data are not now at hand to truly determine the relative merits of wrought iron and steel. These are very much needed.

Much depends upon the thoroughness with which the galvanizing process is carried on. For the best protection pure zinc should be used, and not an alloy. It should be of sufficient thickness and applied so as to thoroughly cover the pipe at all points. The old fashioned dipping process gives best results. Sometimes the galvanized coating is put on by a method of electroplating. This is not satisfactory, for various reasons. Usually the coating applied in this way is much too thin. Wiping a pipe after dipping also produces a thin coat. To obtain a galvanized coating of satisfactory quality it is necessary to exercise great care in its manufacture. In the haste to turn out large quantities of pipe in a short time, there is danger lest the process of galvanizing be slighted. If the mill scale is not properly cleaned from the pipe; if the acid used in pickling is not thoroughly washed off; if the temperatures of pipe and zinc are not right; if the zinc bath is used too long, so that dross accumulates in the dipping tank, and if other precautions are not taken, the galvanized coating will not be satisfactory. Walker has shown by chemical experiments with tin plates that even when the process of galvanizing is carried on in the best possible manner, minute openings in the zinc coating may be detected. These may start corrosion and when once the iron or steel has been exposed at such points rusting will continue. The writer has applied Walker's test to galvanized iron pipes with similar results. In the course of inspection of many pipes taken from buildings and found in the shops of plumbers, it has been often noticed that galvanized coating is very imperfect. There seems reason to believe that many of the rusty water troubles that have been recently experienced are due to the use of poor piping and might have been avoided if better grades of pipe had been used.

At the present time plumbers have difficulty in obtaining gal-

vanized pipe that can be recognized as satisfactory in quality. No one seems to know what requirements to specify, and even if the specifications be properly drawn there is difficulty in making sure that the material furnished complies with them. Comparatively few plumbers are able to tell steel from iron. The threading test has been proved to be unreliable in the hands of many. The filing test is little better. A more practicable method is to saw off a short ring from the end of the pipe and break it with a sledge, the fracture being crystalline if steel, but fibrous if wrought iron. Sometimes even this fails. The chemical tests are, of course, more conclusive, but are not available to the ordinary plumber or purchaser. It is not uncommon for a plumber to specify wrought iron pipe and be furnished with steel pipe or with a mixture of both wrought iron and steel.

Inspections of the galvanizing are seldom made with sufficient care. To inspect the interior of a pipe is difficult, but some idea of the smoothness of the coating may be obtained by throwing a ray of sunlight through the pipe with the aid of a mirror. Roughnesses and bare spots of large size can be thus detected. There seems to be no doubt that while it is possible to obtain good pipe in small sizes there is on the market at the present time a very large amount of steel pipe of inferior quality. There is also some poor wrought iron pipe, but the amount of poor steel pipe is larger, doubtless because more steel pipe is made. In the case of cast iron pipe it is customary for manufacturers to so mark the pipe that it can be identified. This practice is not generally applied to wrought iron or steel pipes of small sizes. Some wrought iron pipe manufacturers brand all pipes larger than $1\frac{1}{2}$ inches in diameter, and one company brands its pipe down to $\frac{3}{4}$-inch sizes. It would be of material benefit to all concerned if the practice of branding pipes for identification should become universal. Mr. A. L. Webster, a well-known sanitary engineer of New York City, has recently investigated the question of the purchase of small sized pipe, and has found the trade conditions existing between manufacturers, agents, dealers and plumbers to be such that it is now practically impossible for a purchaser to know the quality of the pipe that he is paying for. He has rightly insisted, in the case of a large contract, that no pipe shall be furnished that cannot be identified and that cannot be proved to correspond in every respect to the specifications.

What has been said of steel pipes applies with equal force to the material used for the storage tanks.

REMEDIES

If the above mentioned theories of corrosion are correct, the logical methods to be used for preventing rusty hot water would be along the lines of reducing the hydrogen ions in the water or increasing the hydroxyl ions, getting rid of the dissolved oxygen, reducing the temperature, pressure, and circulation; and using pipes of good quality selected with reference to the nature of the water. Practice can follow theory to a certain extent.

There seems to be no doubt that the most effective method of avoiding rusty hot water is to use brass or some other metal other than iron or steel for the hot water pipes and boilers. This increases the expense of the installation, but with very soft waters it is advisable. If brass is used it should be properly alloyed and well annealed; proper fittings also should be used.

If wrought iron or steel pipes are used they should be of the best quality and should be well protected by a galvanized coating of pure zinc applied by the dipping method. Experience appears to indicate that wrought iron pipes of the best grade resist corrosion better than steel pipes, but so many exceptions have been found to this that it cannot be considered as definitely established. Poor grades of both steel and iron pipe are to be avoided. A vigorous reform should be instituted in the manufacture and methods of branding and sale of smaller sized pipe for use with hot water.

In domestic hot water supplies it is not feasible to prevent circulation of the water in the pipes; nor is this desirable, as the circulating system possesses a number of distinct advantages. The pressure of the hot water must depend chiefly upon practical physical conditions, but in designing a system where red water troubles are feared, low pressure should be favored. There seems to be no doubt that in many cases the temperature of the hot water supply is maintained higher than is necessary for domestic uses, and in such cases the red water plague could be materially alleviated if means were taken to prevent excessive heating by the use of an automatic control.

Neither is it feasible nor desirable to remove the dissolved oxygen from a public water supply as has been recommended for the Coolgardie supply in Australia. It is sometimes done in the case of water used for boiler purposes, and the results are said to be beneficial. There is no reason why it could not be done for hot water installations in large buildings, as in apartments, hotels and office

buildings, where large numbers of taps are supplied from a common source. By first heating the water to a rather high degree, say 80° to 90° C., and then carrying it to an open tank at the top of its building a large amount of the dissolved oxygen and carbonic acid as well would be liberated and its corrosive power materially diminished (Table 17). A more complete removal might be obtained by the use of a closed storage tank with a partial vacuum. Whether this method would produce better results than that of a regulated low temperature is something to be determined.

The most effective method of preventing rusty hot water, next to the avoidance of iron and steel pipe, is to reduce the hydrogen ions in the hot water to a minimum, or, what amounts to the same thing, to increase the relative number of hydroxyl ions. This practically amounts to saying that the public water supply should not be too soft. Experience seems to indicate that the alkalinity should be at least 10 or 15 parts per million. The higher the alkalinity the less danger of rusty hot water. But it must be remembered that the hardness of water is in itself objectionable and that when it is more than 15 or 25 parts per million it begins to have a noticeable effect on the use of soap.

Public water supplies high in organic matter and low in alkalinity may be advantageously hardened by the addition of a small quantity of lime, say 10 or 15 parts per million. This practice has long been common in England.

The use of alum with soft, colored waters should be avoided as far as possible, but if it is employed lime (or soda) should be used with the alum in order to prevent the alkalinity from falling too low. But here again is a difficulty, for when deeply stained waters are decolorized with alum it is found that the additional use of lime and soda prevents to some extent the satisfactory decolorization of the water. In such cases considerable care must be used in adjusting the chemicals, and in the present state of the art it is not always possible to obtain entirely satisfactory results. The problem of color removal for soft waters has not yet been satisfactorily solved.

With hard waters where the hardness is due to carbonates practically no precautions are necessary to be taken, as the hardness itself seems to be sufficient to prevent rusty water troubles.

Finally, it is evident that the problem of rusty hot water is a complicated one. Its solution demands the united efforts of water works engineers, plumbers, and pipe manufacturers. Economy to

the householder demands that the quality of the public water supply be considered not alone from the hygienic standpoint but from its possible influence on pipes and fixtures, and that on the other hand the materials used for distributing the water be chosen with reference to the inherent qualities of the naturally available supply. Plumbing regulations should be drawn with this in mind. But all these precautions will be of no avail if pipes of satisfactory quality cannot be obtained and recognized by the ordinary dealer and plumber. To this end two things are necessary, properly drawn specifications and a simple method of branding.

DISCUSSION

Mr. Diven: The speaker's experience with two water works systems has given some data concerning red water troubles. The first system with which he was connected furnished unfiltered water from two different sources—one a very soft water, the other ranking as hard water. No trouble was complained of as to red water in either system. The soft water was used perhaps one-quarter of the year. A filter plant was put in about eight years before he left this plant—the Jewell mechanical gravity type. Only one complaint of red water was ever made during his connection with these works, this was in a new apartment house, where they had great trouble. The speaker called their attention to the probability of its being due to the character of the heating apparatus, which was a tubular ungalvanized wrought steel boiler, or to the piping, showing them conclusively that no other houses on the same block had this trouble, also making tests of boiling the water in porcelain kettles, showing no increase in color whatever. This apparatus was overhauled and the tubes taken out and the trouble was never heard of again.

In the second instance there has been almost constant complaint of red water in the hot water systems. This water is of a very different character, being a soft, peaty water, coming under classes 3 and 4, very high in organic matter. The water was also high in color, ranging about 130, and when the service was first started contained as high as 3½ parts per million of iron. The water is a surface water stored in a large shallow reservoir, and has changed somewhat from time to time. A typical mineral analysis is given below:

RESULTS IN GRAINS PER GALLON	MINERAL	RESULTS IN PARTS PER MILLION
0.087	Silica SiO_2	1.50
0.008	Iron Fe_2O_3	0.14
0.050	Aluminum Al_2O_3	0.85
1.622	Calcium CaO	27.75
0.285	Magnesium MgO	4.85
0.242	Sodium Na_2O	4.14
0.346	Potassium K_2O	5.92
1.526	Sulphates SO_3	26.10
0.014	Nitrogen NO_3	0.25
1.286	Chlorine Cl	22.00
0.350	Carbon dioxide	6.00
6.023	Total Solids	103.00

The water is also high in dissolved oxygen. This water is also filtered by the Jewell mechanical type filters after passing through coagulating and sedimentation basins, equal to about two days supply. About two grains of alum have been used, and at times it has been necessary to add lime or soda ash to increase the alkalinity which is low in the raw water. Some three years ago, to test the cause of these complaints, the speaker put in an experimental hot water apparatus in the office building, using about 150 feet of black or ungalvanized steel pipe in one circulating line and the same amount of galvanized steel pipe in the other. The heating apparatus was an ordinary laundry stove with a cast iron water front, the boiler an ordinary galvanized one. Fire was kept almost constantly, and the pipes so arranged as to make a complete circulating system so that the water was hot throughout the entire pipe system at all times. The ungalvanized steel pipe soon demonstrated that it was unfit for this service, and this was abandoned and records not kept as they showed water too high in color after heating, to be serviceable. The galvanized steel pipe system was kept in service for about two and one-half years, the average results being as follows:

Color of water before heating	23.8
Color of water after heating	72.9
Iron before heating	0.11
Iron after heating	1.7

The color produced by heating was rather high, enough so to be objectionable from an aesthetic standpoint.

A short time ago the circulating pipe system was changed to what

the speaker purchased for a strictly wrought iron pipe; it did not, however, fully hold up to the test, and he is in some doubt about its being wrought iron. The average results of the use of this pipe were no better than with galvanized steel, being as follows:

Color before heating	23.4
Color after heating	78.1
Iron before heating	0.18
Iron after heating	1.411

The same heating apparatus and hot water boiler was used as with the steel pipe, about 180 feet of the wrought iron pipe was used.

After this he put in a heating apparatus with a brass coil and a copper boiler, using first galvanized iron pipe and afterwards galvanized steel for the circulating system. These tests have not been run for any great length of time; the average results are as follows:

With Wrought Iron Pipe

Color before heating	22.7
Color after heating	22.0
Iron before heating	0.12
Iron after heating	0.23

With Steel Pipe

Color before heating	23.0
Color after heating	21.0
Iron before heating	0.11
Iron after heating	0.21

The results seem to be about the same for the two kinds of pipe. The strange part of it was there was an actual reduction in color instead of an increase—the increase in iron being about 0.1 part per million. The test with the brass heating coil and the copper boiler has only been run for a short time, but will be continued, and if results vary will be reported. The general result, however, only carries out the speaker's original theory that the trouble from red water was due, not to the character of the water as much as to the character of the heating apparatus and poor quality of pipe used.

MR. HERRING: I think Mr. Whipple has given us the best summary on this subject that we now have in our literature; and it certainly is a very important one. It reminds me of the efforts that were made many years ago in England to explain and overcome the same troubles. Some thirty years ago I believe experiments were

made in the Whortley Iron Works in Scotland by a Mr. Andrews, and he published his results in numerous papers of the Institute of Civil Engineers' Institute of Naval Architects, and several others which I remember seeing at that time and which interested me very much. Those experiments seemed to throw new light on the subject of the corrosion of iron at that time and I recall making a short report of it at the Engineers' Club in Philadelphia. He made the experiments in a very scientific manner, in order to find out the cause of corrosion. He experimented with cast-iron, before and after it had the surface layer chipped off. He experimented also with steel, of several different grades, with the ordinary commercial wrought iron, and with what he called the best Whortley wrought iron. The results were interesting in this way, that he found a cause for the corrosion in these metals when they were all treated alike and submerged in the same water, which was made sometimes alkaline, sometimes acid, sometimes salt. This cause was an electric action, the materials forming galvanic batteries. Those papers are of course in the literature, and are accessible. What interested me most was that the Whortley wrought iron gave the greatest resistance against corrosion. At that time this was rather a surprising result. The material was rolled over and over so that all the uncombined carbon was practically out of it. It was almost a pure iron. The ordinary commercial iron had a lot of uncombined carbon in it. The steel had less and the cast iron had the most, excepting those samples which were covered with the natural coating formed in casting, which is a magnetic oxide and resists corrosion to a great degree. Mr. Andrews explained the results by the belief that the iron and the uncombined carbon together, with the slight acidity of the water, due to carbonic diacid, operated as a galvanic battery, the current thus set up being the cause of the corrosion. Where you have pure iron and no carbon, no such battery effect follows, consequently there is no current and no corrosion. In the proportion as the uncombined carbon increases in the metal just so does the corrosion increase.

A practical application was made of this by the former Chief Engineer of the San Francisco water works, Mr. H. Schussler, who found that nothing but the best wrought iron pipes would suit him. He used this material very largely in the Spring Valley Water Works of San Francisco and had the wrought iron plates made in Harrisburg, Pa. His specifications were drawn so that he was sure of the practical removal of the uncombined carbon. I saw some of those pipes a few years ago lying out in a field. Mr. Schussler told me that they had

been lying there for two years; they had a very few spots of a brownish color upon them, while not far away there was some commercial wrought iron that had been lying there for hardly a year, and through which you could drive your fist. You know that ocean breezes contain a little acid, which corrodes impure iron very rapidly.

This has always been a very interesting question to me and I have believed that many of the phenomena connected with the corrosion of iron can be better accounted for and explained on the theory of electrolytic action than in any other way.

MR. SPELLER: It seems to me that Mr. Whipple's carefully prepared paper should lead to a practical discussion of the very important question of how best to remedy this trouble with hot water. He brings out two principles that may be applied to the protection of conduits carrying hot water, namely deaëration, and the treatment of the water with lime in order to reduce the proportion of hydrogen ions present. In regard to the latter probably most of you are familiar with the trouble in Australia with corrosion in the Coolgordie conduit and the recommendations that were made to overcoming that difficulty. The other day I received a communication from the Australian representative of the company enclosing a letter from the Australian water commissioner stating that the lime treatment was started experimentally on the 5-inch Mannesman Kalgoorlie-Kanowna main, which is twelve miles long and was laid in 1904, on May 20, 1909, and stopped on July 13, 1910, the quantity of lime added to the water being about 6½ grains per gallon. This treatment was applied in order to remove the carbonic acid and render the water slightly alkaline. The history of the experiment is very interesting, especially in connection with the matter brought up by Mr. Whipple. It appears that this main gave no trouble for practically four years after it was laid, the number of perforations from August, 1904, up to October 27, 1908, being but two. The perforations then began to develop, and in the next seven and a half months numbered 83. About that time, on May 20, 1909, they started treating the water with lime in the proportion stated. In the next six and a half months the perforations decreased to 35. In the next three and a half months they practically ceased, being reduced to five. In the next four months they had no trouble whatever, using the same water under the same conditions, and on the 18th of July, 1910, the lime treatment was stopped. For the next ensuing three and a half months there was no trouble experienced with the pitting, but in the next five

months the number of perforations had gone up to four. Probably a coating of lime had formed on the inside of the pipe during the period of treatment which had a beneficial effect for a short time afterwards.

This data seems to indicate that the treatment is effective, but of course we cannot apply this method to all water. In the case of hot water for apartments, hotels, residences, etc., it would be objectionable to increase the hardness; but I see no reason why the air cannot be removed from water while it is being heated, the indications are that the result would be equally beneficial.

Regarding the question of iron vs. steel, I happen to have been charged with the responsibility of making a special investigation into this subject of corrosion of pipe, and the results which we have observed during the past five or six years have led us to abandon the manufacture of wrought iron pipe entirely although before that we had been making considerable wrought iron. One consideration that has influenced us in this decision is the greater homogeneity of modern steel pipe. I would like to impress that point upon you, particularly, for the steel that is used in the manufacture of pipe is not the steel that is used in the manufacture of other rolled products. It is not possible to make the best pipe with steel that would be quite satisfactory for every other purpose. In the process of manufacturing welded pipe, the pipe must be able to withstand the ordeal of passing through the welding furnace. Anyone who has seen the process will recognize that the metal must be homogeneous, must be uniform and must be free from irregularities, or it is likely to develop blisters or go to pieces in the furnace or not weld. Some is usually lost in the process of manufacture due to the fact that the metal is not up to the standard of homogeneity, and in the case of wrought iron it is considerably more than in the case of soft steel due to the fact that wrought iron, no matter how carefully made, is not as homogeneous as pipe steel as made under present day methods. All our efforts are along the line of improving the uniformity of the metal both as to its chemical composition and also in respect to uniformity and density by increasing the amount of mechanical work that is put on in the course of manufacture. This conduces to better mill practice, it helps pipe manufacturing and at the same time adds to the durability of the product.

The kind of pipe used is largely in the hands of the engineer. Pipe should be ordered under specifications. We would be very glad to coöperate with any movement along that line. At the present time

there are a number of weights of pipe each suitable for certain purposes, when pipe is ordered without any specifications the contractor is very likely to select the cheapest that he can find whether in steel or in iron rather than that most suitable for the purpose. Of course steel pipe can be made of any thickness, and with any reasonable amount of zinc coating that is required. It is somewhat easier to galvanize steel pipe than it is wrought iron.

The question of specifications is a very important one. In our efforts to improve the product I think we would be materially helped if there were standard specifications to work to.

As regards the marking of pipe, nothing is accomplished unless it is carried out with uniform effect; the present methods are somewhat erratic. When a suitable method is found that will not interfere with the use of the pipe we will be glad to adopt it. We hope to have a satisfactory scheme for rolling raised letters on both butt and lap welded pipe before long but the problem is a difficult one in the case of butt welded pipe.

I would like to ask Mr. Whipple, in conclusion, what basis he has for the opinion that good iron is better under corrosion than good steel; also, how he would define good iron with respect to pipe?

Mr. Chester: Going back to red water, my experience has all been to the contrary of that of Mr. Whipple. I think our chief troubles from red water have come from underground water supplies, with one exception, that was at Shreveport, La. At that plant, the water is very hard, and is red originally as it comes from the Red River, which river obtains its name from the color of its water. That water after being filtered gives us red water troubles. It is a very hard water. Our other source of red water was through Indiana. At Kokomo and Muncie, Ind., they obtain their water from a slaty limestone which is full of crevices and underlies the ground I should say at an average depth of from five to twenty feet all over the gas belt of Western Ohio and Eastern Indiana. Most of the cities in that belt obtain their water supplies from this limestone strata, and it is very productive of red water troubles, not only in the hot but in the cold water. It first forms a red substance around the inside of the pipe, which sooner or later becomes black. When you turn on a hydrant to flush out the pipes you first get ink, but in the hot water boilers you get red water. Red water troubles prevail almost universally where we use ground water. The softer the water, the less trouble we have with red water. Jamestown, N. Y.,

the softest underground supply of which I know, gives us little or no trouble with red water. As I understood Mr. Whipple's statement in regard to the sources of red water, it was not from the harder water but from the soft water.

Mr. Whipple mentions lead pipe not being used on account of its being too expensive. In Pittsburgh, lead is not equal to brass. Warm water there eats out lead with a much greater rapidity than the cold water destroys iron pipe. Brass pipe is the only reliable means of distributing hot water through Pittsburgh houses.

Mr. Whipple's statements that red water troubles are primarily caused by the corrosive effect of the water on the tanks and service pipes through which the water flows is, so far as my experience goes, in error, for in the case of Muncie, Ind., where these troubles might have been termed "fierce" they were eventually overcome by iron removal.

We should think that in well-made hot water heaters, copper coil would be used exclusively. We would naturally expect serious troubles from the use of either iron or steel pipe in such instances.

In regard to troubles from red water originating after filter installation we would be prone to characterize this as due to poor operation, admitting, however, that we can't keep our cake and eat it too. Filtration naturally hardens slightly and provides some sulphuric acid that did not previously exist but this may be so minimized by careful operation, that the effect could be negligible. We have had experience in several cities in the removal of color from soft waters and have found carbonate of lime and sulphate of alumina the most effective re-agents, and after more than ten (10) years, have had no complaints from red water or objectionable features similar to those outlined by Mr. Whipple.

Mr. Fisher: I would like to ask the last speaker whether the perforations in the main he referred to all occurred from the inside, or whether some of it was on the outside?

Mr. Speller: This was internal corrosion.

Mr. Fisher: We have wrought iron pipe in use that was made thirty-eight years ago; part of it is $\frac{3}{16}$-inch, part of it, $\frac{1}{4}$-inch, and there is no pitting on it. We also have steel pipe made seventeen or eighteen years ago that has a large number of pits.

MR. WESTON: This paper is so complete and so full of valuable data that discussion of most of it is quite superfluous. One can only add a little confirmative data from his own experience.

The speaker agrees with Mr. Whipple that the waters most apt to corrode metal are soft waters free from protective coloring matter, and it is unnecessary to emphasize the theory of this action. In May, 1909, the speaker inspected the wells and supply of the Rumford Falls (Me.) Light and Water Company where the inhabitants were suffering from a "red water plague" not only in the hot-water but also in the cold water systems. The water contained 64 parts of carbon dioxide per million and 2.8 parts of oxygen. On its way to the town this water took up a large amount of iron from the pipes in addition to the 0.5 parts per million contained on the average in the well water. At times this increase amounted to 5 parts per million.

Previous to the writer's visit, the company had engaged a consulting chemist who advised the aëration of the water on its way from the wells to town. This reduced the carbon dioxide in the water from about 65 parts per million to about 7.2 parts per million. It also increased the dissolved oxygen from 2.8 to 13.7 parts per million, as the following table shows:

SOURCE OF SAMPLE	PARTS PER MILLION	
	Carbon dioxide	Dissolved oxygen
Wells	6.5	2.79
Aerator effluent	7.2	13.70
Tap in town	8.4	6.80

At the same time that the above changes took place in the gaseous contents of the water, the iron had increased from 0.5 to 1.3 parts per million. It will be noted that the oxygen diminished between the aërator and the tap in town, and that the carbon dioxide was practically unchanged owing to the fact that the iron was being continuously dissolved and precipitated, the oxygen combining with the iron to form oxide. The result has been that while the aëration of the water has reduced corrosion because of the removal of excessive carbon dioxide, the removal has not been so complete but that considerable corrosion, oxidation and precipitation takes place. It is also true that the pipes are gradually accumulating considerable amounts of iron rust.

Of especial interest in this paper is the experiment with colored

waters made from extracts of old and fresh leaves, given in Table 11, and showing the difficulty of precipitating fresh dissolved, organic matter from colored waters, as well as the ease of precipitating old organic matter. It is a well-known fact that this coloring matter settles out in service pipes and protects them against the corrosive action of the water. The speaker has observed this fact in numerous instances, and at Exeter, N. H., and other places has observed that the removal of this coloring matter by filtration has been followed by complaints that the water showed an increased corrosive effect in the hot water systems. These effects have been similar to those which occur when there is a change from a colored surface to a clear, soft ground water supply.

Regarding the addition of soda ash to prevent undecomposed and unprecipitated alumina from passing through the filter, the speaker would say that at several mechanical filter plants in New England it has been found necessary to maintain an alkalinity of at least 8 parts per million in order to produce a non-corrosive effluent. Furthermore, it has been observed in practice, and the speaker has corroborated this observation by repeated experiments, that the addition of an amount of soda-ash chemically equivalent to much more than one-half the amount of sulphate of alumina added tends to destroy the coagulation of the water, and the addition of excessive amounts will actually prevent it. In cases like this lime seems to be a better alkali to use, especially as its use would cause an increased hardness which would tend to diminish corrosion.

Those who have had the good fortune to visit the splendid new plant at the National Tube Works at McKeesport, Pa., will realize what great progress has been made in the manufacture of steel pipe in the last few years. On the other hand, engineers in general believe that wrought iron pipe is less corrosive. It is certainly true that homogeneous metal is a necessity and that poor wrought iron pipe is nearly as bad as poor steel pipe, even though the best steel pipe be equal to the best iron. The possibilities of the so-called ingot iron in this connection are worth considering, although small sized pipe has not yet been manufactured from it. This metal is free from any manganese and carbon, the former of which at least is a great aid to corrosion. This metal is available now in sheets, and, if it could be tried for hot water tanks, the experience would be useful. Cement lined iron pipe and wood pipe, so frequently used to avoid corrosion in cold water services, cannot, of course, be used in contact with hot water, and one must look to the manufacturers of homoge-

neous or electrolytically inactive metals for use in contact with hot corrosive waters.

MR. CHESTER: My experience has all been to the contrary of that of Mr. Whipple. I think our chief troubles from red water have come from underground water supplies, with one exception, that was at Shreveport, La. At that plant the water is very hard, and is red originally, as it comes from the Red River, which river obtains its name from the color of its water. That water after being filtered gives us red water troubles. Our other source of red water was in Indiana. At Kokomo, Indiana, they obtain their water from slaty limestone which is very full of crevices and underlies the ground I should say an average depth of from five to twenty feet all over the gas belt of western Ohio and eastern Indiana. Most of the cities in that belt obtain their water supplies from that limestone strata, and it is very productive of red water troubles not only in the hot but in the cold water. It first forms a red substance around the inside of the pipe, which sooner or later becomes black. When you turn on a hydrant to flush out the pipes you first get inky water, but in the hot water boilers you get red water. Red water troubles prevail almost universally where we use ground water. The softer the water the less trouble we have with red water.

Jamestown, N. Y., I believe, gives us little or no trouble with red water. As I understood Mr. Whipple's statement in regard to the sources of red water, it was not from the harder water but from the soft water. I would like to hear further from him on that.

MR. WHIPPLE: Mr. Speller asks about the difference between good and bad iron. It seems to me that the difference is about as hard to define, as that between a bad trust and a good trust. All water works men, however, know by practical experience that there is a difference between bad iron and good iron and they are as anxious as anyone to have the chemist tell just how it is possible to draw specifications so as to obtain iron or steel of good quality. A few days ago I had occasion to use some wrought iron pipe that was purchased for experimental purposes with the expectation of getting a first-class article. The first lot of pipe furnished was of excellent quality, but the second lot was absolutely different from the first lot, the galvanizing especially being very poor. The two lots came from the same dealer and were supposed to be the same, but evidently they were not made by the same manufacturer.

In commenting on the relative advantages of good and poor iron or steel I have doubtless been drawing rather more from the experience of my friends than from my own, but it does seem to me that general experience has been that the old wrought iron pipe resisted corrosion somewhat more readily than the newer pipes. At any rate, in the cities with which I am familiar where these red water troubles have occurred, the pipes that were put in many years ago have given relatively little trouble, whereas pipes of more recent construction have given most trouble. This is a question upon which we need something more than opinion. We need the careful collection of actual facts and one of the principal reasons that induced me to prepare my paper was to stimulate research along these lines.

In regard to the question raised by Mr. Chester and his allusion to corrosion by a very hard water, it seems to me that the instance mentioned by him must be looked upon as an exceptional case. It is certainly true that in general there are more red water troubles with soft waters than with hard waters and it makes no difference whether these are well waters or surface waters. Yet, as pointed out by him, some hard waters are corrosive. This usually happens from one of two reasons,—either the dissolved free carbonic acid in the water is very excessive, or the hardness is due to sulphates and not to carbonates. This leads me to think that possibly in my paper I did not sufficiently differentiate between temporary hardness due to carbonates and permanent hardness due to sulphates. The sulphates of calcium and magnesium apparently do not exercise the same protective effect against corrosion as do the carbonates of calcium and magnesium.

I realize that this whole question is an extremely complicated one and I should be glad to learn from any member of the association who may have had experiences that differ from the general experiences referred to in my paper.

Mr. Chester: Red River water has as high as 600 p.p.m. hardness in the summer-time, as shown by analysis; that was sulphate hardness, and it was the worst red water we ever had.

Mr. Berry: We have deep well water. Our wells are 1375 feet deep; we go down into what is known as the Potsdam sandstone; and that water comes out from the wells perfectly clear and almost chemically pure. After it stands in the mains three or four weeks it turns red. When we flush out a hydrant it first comes out black for a few

minutes, then becomes a brown coffee color, leaving a sediment on the pavement. We are having a great deal of trouble. I would ask for information whether any of the brothers know any way of treating that water to get rid of this red color that we are troubled with? It has caused a good deal of complaint among our patrons, especially in the washing of clothes. It stains the clothes, and it is almost impossible to remove the stain. We have less trouble with it on the dead ends where water is not used much than down town where there is a lot of water used. In a number of places we find that it is closing up the smaller service pipes, and the queer thing to me is that right where the pipe is the smallest and the velocity is the highest there is the place that it closes up first. In the $\frac{3}{4}$-inch pipe there will be but very little clogging, but right at the connection we find the pipe almost shut out. It is soft matter; you cannot wash it out no matter what pressure you put on; but you can take a stick and scrape it off the inside of the mains near the pumping station in big handfuls. I would like it if any present who have had any such troubles will give me a little information.

President Alvord: Sounds very much like crenothrix.

Mr. Berry: Does crenothrix appear in water drawn from wells as deep as ours?

Mr. Diven: Yes.

Mr. Steadman: While I am in the business I feel a little timid in talking before the association members; but I have had the same troubles that Mr. Berry has. I had Prof. E. T. Smith, of Beloit, about a month ago investigate with me as to where it comes from. Our water is absolutely pure by chemical analysis; but I get that same sediment in the pipes and if we increase the pressure for fire purposes we get the inky water such as the speaker spoke of awhile ago, very black water. He is trying to cipher out where it comes from. I came here for information. I could not on account of the noise and poor acoustic qualities of this hall get the drift of the gentleman's paper, and am going to await with anxiety the receipt of the printed Proceedings and see if I can get at something that will help.

Mr. E. E. Davis: We have what is said to be the finest water in the world in Richmond (Virginia). I have listened to this paper

very closely. Mr. Whipple has touched on a great many subjects of exceeding interest to me, especially as to wrought iron and steel pipe. Our water rusts out wrought iron pipe in about ten years; I have never used any steel pipe. Galvanized pipe lasts about twenty years.

Mr. Gwinn: By way of information I would suggest that the troubles of Messrs. Berry and Steadman, as the President has suggested, are caused by crenothrix; in other words there is a large percentage of iron in the water which furnishes the food for the crenothrix. A good plan would be to see Mr. Smith at Freeport, Ills., who has had similar trouble and found out how to treat the water so as to precipitate the iron, and then filter the water, with very satisfactory results.

THE INTERPRETATION OF WATER ANALYSES

By Daniel D. Jackson

In former years, when waters were judged merely from their chemical constituents, many serious misinterpretations of their sanitary quality were made. Waters of great bacterial purity were condemned because the free ammonia or nitrites were above certain standards and waters practically free from organic matters were given a clean bill of health, when they may have contained the germs of specific disease.

With our present knowledge of the subject, we examine carefully into all phases of the determinations and weigh each according to its merits. Water analysis has become, year by year, more complicated and extended and now requires specialists to properly carry out the determinations necessary, but also, year by year, more light has been shed upon the true requirements for water from sanitary and from aesthetic standpoints.

In the days when to add a little silver nitrate to a water and note the amount and nature of the precipitate produced, was the means of examination, the matter was a simple one, but in the light of our present knowledge, it was entirely worthless. Now the analysis requires a specially equipped laboratory and a highly trained analyst to accomplish the result, and he must change and improve his methods, from year to year, to keep up with the constantly growing knowledge in relation to the very numerous intestinal diseases which may be transmitted by impure water supply.

Also in former years epidemics of intestinal diseases were almost invariably attributed to water supply. We now know that while they may come from water, they are as often, or perhaps more often, the result of the improper disposal of sewage and garbage, particularly in towns where there are still in use open privy vaults, or where excreta is allowed to accumulate in open lots exposed to flies, rats, mice or other vermin. A proper realization of these facts leads the sanitarian to less often attribute epidemics of intestinal diseases to water supply, particularly those occurring in the summer and fall, unless the proof is more positive than that which has often been formerly taken.

There are four main divisions in the examination of water, namely: physical, chemical, microscopical and bacterial.

PHYSICAL EXAMINATION

The physical examination includes the temperature, turbidity, color and odor. The temperature at the time of collection may give an indication as to the source of an underground water, whether shallow or deep, or in the case of a surface water, it may have a bearing on the number and kind of microscopic growths occurring or likely to occur in the water. It is, of course, important to keep down the temperature of water used for drinking purposes.

The turbidity is a measure of the suspended matter. The figures represent the relative cloudiness of the water. This suspended matter or turbidity may be mineral, vegetable or animal in its nature and the chemical and biological results determine this point.

The color of the water may be affected by the turbidity, so that strictly speaking, the water should be filtered before the color is taken, or the color may be stated as filtered and unfiltered. The true color represents matter dissolved in the water and is usually leaf or other vegetable extract containing iron.

The odor of a water may be due to dissolved vegetable or animal matter, or may be due to microscopic plants or animals. These odor producing organisms are in no way associated with disease organisms and have a bearing only on the æsthetic quality of the water.

CHEMICAL EXAMINATION

The chemical examination shows the products of living matter which are or have been in the water, such as the various forms of nitrogen present. It also shows the varieties of dissolved mineral matter which the water has taken up in passing over or through the soil.

The products of living matter which are still living or only partially oxidized, when extracted by the water, are represented by what is called nitrogen as albuminoid ammonia. This nitrogen may come from microscopic plants or animals, from bacteria or from extracts of larger plants or animals. Such extracts as come from the leaves or roots of trees and grass may dissolve in the water but be as harmless as is the colored organic matter in a cup of tea. Or it may come from animal contamination direct or from manured fields in which case it may be very harmful.

The nitrogen as free ammonia, nitrites or nitrates represents what was originally albuminoid ammonia, which has been to a greater or lesser degree oxidized, the nitrates being the highest degree of oxidation and therefore showing contamination which has passed and become ineffective. Considerable amounts of nitrogen as free ammonia and nitrites do not necessarily show present contamination but may show merely a lack of proper oxidation or also the reduction of what has previously been nitrate. This sometimes occurs in deep wells where the oxygen content is low, or it may occur in the presence of a large amount of microscopic growth in the water. The sanitary quality of such waters should be judged chiefly from their bacterial contents.

The only other feature of the chemical analysis having a bearing on the sanitary quality of a water is the chlorine which may be found to be above the normal amount present in the region from which the water comes. If near the sea, the chlorine is high as it blows in as salt spray from the ocean and is precipitated in the rainfall of the region. On the Atlantic Coast as far west as Ohio, lines of equal chlorine may be mapped out which are practically parallel to the coast line. The amount of common salt or chlorine in the water above the normal for the region is the amount which comes from animal drainage and represents present or past contamination. Whether the contamination is past and therefore not effective may be shown from the rest of the analysis particularly from the bacterial results.

The total solids obtained by evaporating the water show the total amount of mineral, vegetable and animal matter present. The loss on ignition is the vegetable and animal matter but may also represent some water and combined carbonic acid in mineral combination and the difference between the total solids and the loss on ignition respresents the fixed solids or purely mineral matter.

Included in this purely mineral matter is the common salt before mentioned, the hardness, the alkalinity and the iron. The remainder usually undetermined is more often chiefly silica, but may have various mineral constituents.

The hardness or soap destroying power of the water is made up of lime and magnesium carbonates, sulphates, chlorides and nitrates, that is, the various lime and magnesium salts dissolved from the soil. The alkalinity consists of all carbonates present.

The iron or manganese are determined to see that they do not occur in amounts sufficient to precipitate and cause an objectionable turbidity or the staining of clothes in laundry work. Usually the

iron is unobjectionable in amounts below 0.5 of one part per million, while somewhat lower amounts of manganese may cause precipitation in the water.

MICROSCOPICAL EXAMINATION

Microscopical examination shows the number and kind of microscopic plants and animals in the water. These have a bearing only on the tastes and odors which they may develop. The animals or their eggs which may cause intestinal diseases are not at the present date distinguishable from other forms. In fecal matter many forms of disease, including ciliated and flagellated infusoria and various types of worms may be determined, but no work of this nature has as yet been developed in water analysis.

Certain of the common organisms produce strong tastes and odors in the water, due to the development of essential oils, while many other organisms even when occurring in large numbers do not cause more than a turbidity in the water. The microscopical plant growths may also increase the wash water where filters are used. They are all elimitated by proper treatment with copper sulphate, but some require larger doses than others to complete their removal.

BACTERIAL EXAMINATION

The bacterial examination is all important in the sanitary analysis of water. The number of bacteria per cubic centimeter gives evidence of the quality of the water but the species of bacteria present is of most importance.

The intestinal bacteria are determined by a solution of oxgall, peptone and lactose and the fermentation of this solution shows their presence; the dilution used giving an idea of their numbers. A low number may be admissible in surface waters, but B. coli should not often occur in as small an amount as one cubic centimeter. In ground waters no B. coli should occur.

The enormous numbers of B. coli which ordinarily occur in the fecal discharge of man and other warm-blooded animals render the test for B. coli in the water one of great delicacy. This bacterium is in itself entirely harmless, but its occurrence shows the possibility of the presence of any one of the many forms of intestinal diseases, the germs of which would of necessity be accompanied by large numbers of B. coli. If the B. coli are numerous, the water is of suspicious character and tests may then be made for the various

species of specific disease bacteria, such as the typhoid bacillus, the cholera spirillum, the disentary bacillus or the series of spore forming bacteria which produce intestinal disturbances, such as the B. welchii, B. sporogenes, B. edematis, etc., all of which may be isolated by a broth made from beef liver.

The animal infections and the spore forming bacteria are not affected by hypochlorite treatment in the dilutions ordinarily applied and are only removed by long storage or filtration.

These spore forming bacteria have been isolated by the author from several infected water supplies as well as from infected feces. They are particularly virulent among small children and much more stress will be placed upon them in the future than has been in the past.

From what has been said it is evident that the bacterial examination of water is of decided importance and while the physical, chemical and microscopical examinations tell much about the condition of the water, the bacterial examination gives the strongest evidence as to its sanitary quality.

THE PURIFICATION OF DRINKING WATER

By Dr. John L. Leal

The importance of water to the human economy cannot be overestimated. It is illustrated by the fact that it constitutes about 70 per cent of the entire weight of the body, even in the teeth there being 100 to 1000 parts. It is universally present in all the tissues and fluids of the body; in the blood, in the secretions, where its presence is necessary in order to give them the fluidity which is necessary to the performance of their functions, for it is by the blood and secretions that new substances are introduced into the body and old ingredients discharged. It is necessary, both for the introduction and discharge of substances naturally solid, that they should be for the time being in a fluid form. Water is therefore an essential ingredient of the fluids, for it holds their solid materials in solution and enables them to pass and repass through the animal form. It is also an ingredient of the solid and semi-solid tissues, being necessary to give them the special consistency which is characteristic of them and which would be lost without it, thus interfering with their functions.

Water is taken into the body in the form of drink and in the food, all of which contains a larger or smaller quantity of water. In the living body it takes part in the vital functions principally by its physical properties; it is a universal solvent of all ingredients of the animal fluids, holding them in solution either by direct liquefying power or by the aid of other substances which are themselves soluble. It thus enables the nutritious elements of the food to find their way into the circulating fluid, and penetrate the substance of the solid organs. It permeates the organized membranes of the body and brings into contact with each other the inorganic and organic materials and enables them to assume new forms by their mutual reactions. It thus takes part in the phenomena of absorption, transudation, exhalation, and even of chemical union and decomposition, which make up the internal nutritive functions of the human body. After performing its part in these vital processes, it is discharged from the body, bringing with it various ingredients which it has absorbed from the substance of the glandular organs, such as salts and

excrementitious matters, animal vapors and odoriferous material of various kinds.

Water, thus playing so important a part in the human economy, it will readily be seen should be pure and wholesome. First, it should not contain sufficient organic or inorganic matter to interfere with its solvent properties, it being, as already stated, the great solvent of the body; and, second, it should not carry into the human body specific germs of disease, which science has proven it is possible for it to do.

Water is originally derived from the atmosphere by means of condensation and precipitation, in the form of rain, snow, dew or fog. It is common belief that water so derived, and before reaching the earth, is clean and pure. This is only approximately true, because the rain-drop, the snow-flake, and even dew and fog, carry down with them whatever impurities may chance to be in the atmosphere through which they pass. These impurities may be organic or inorganic, derived from dust, smoke, etc. Either alone or in connection with these dust particles may also exist living germs, even those of disease. The effect, therefore, of such precipitation is to cleanse the atmosphere, and to fou to a greater or less degree the water reaching the earth. The degree of foulness depends entirely upon the condition of the atmosphere through which the water passes, that falling through the atmosphere above a city being much more foul than that falling upon a sparsely inhabited or an uninhabited region. On reaching the earth, such waters take up much more polluting matter, derived either from the earth itself or from materials deposited upon its surface; such pollution being organic and inorganic, soluble and insoluble, living and lifeless. It dissolves some substances and sweeps along others mechanically. If it falls upon earth not already clogged, but porous and absorbent, it will sink by gravity until intercepted by some impermeable layer. This is called vertical displacement.

The upper layers of the soil are teeming with bacterial life and more or less of these bacteria are displaced mechanically and carried downward with the water, as are also other matters, organic and inorganic. It also dissolves various inorganic substances contained in the rock or soil, and various reactions, physical and chemical are set up and continue until the process for some reason is interrupted or the material present is exhausted.

Water thus making its way into the ground by vertical displacement is commonly called "ground water," and, as a rule it is organ-

ically of a high degree of purity, the earth acting as a filter, straining out the bacteria and various other substances carried by it, and such purity is further increased by the various chemical reactions which take place.

Although this is the usual result, still it does not necessarily follow. The soil may be of so loose a character that the necessary straining effect does not take place and the vertical displacement of the water may be so rapid, that there may not be time for the necessary chemical reactions to take place; or crevices may exist which will allow practically surface water to reach the end of the displacement, to appear again upon the surface through springs or wells.

Many severe epidemics of both typhoid fever and cholera have been traced to such wells or springs.

Another very serious defect present in ground water is due to its solvent action upon various inorganic substances and its absorption of the various salts resulting therefrom, causing so-called hard waters, many of them to the degree of being decidedly unpleasant to the taste and practically unfit for domestic use.

There can be no doubt, however, that ground waters, with the exceptions noted, are the purest of which we know, and for small supplies, where they can be obtained, they answer the purposes of public supply better than any others. It is only under exceptional circumstances, however, that ground water can be obtained in this way in large quantities, so that for large supplies we are forced to use the so-called surface waters, or waters which flow by horizontal displacement. That is, instead of sinking into the ground, as do the so-called ground waters, they flow over the surface of the watershed and are collected into brooks, rivers and lakes.

It can readily be seen that these surface waters must of necessity be more polluted than the so-called ground waters, because in flowing over the surface of the earth, they must either dissolve, or carry along with them mechanically, a large proportion of polluting matters existing upon such surface. Such waters, as a rule, do not contain as much inorganic matter as do the ground waters, usually being much softer, more agreeable to the taste and more useful for the purposes of a public water supply; but such waters, unless falling upon uninhabited watersheds, must of necessity possess certain elements of danger. There is always the possibility that, should typhoid fever or cholera exist upon a watershed, the specific germs to these diseases may be carried along with the other matters in their horizontal displacement. Indeed, I think I may say that it is

the generally accepted opinion among scientific men today, that no surface water coming from a populated watershed is safe for the purposes of a public supply without some form of purification.

There was an old and generally accepted theory, which exists to some extent even today in the minds of the public, that running water purifies itself. This is but partially true. Some slight degree of purification may take place by the death of bacteria, their deposit upon the mud or sand at the bottom, a slight degree of chemical purification and a considerable dilution by pure ground waters reaching the streams. This element of dilution by ground waters was overlooked when the original belief was formed, although it is undoubtedly the most important factor present, and accounts to a very large extent for the improvement in appearance of the water at a point lower down than where the gross pollution enters. The pathogenic germs, however, which are the source of danger, may no doubt be carried indefinite distances from the point of introduction and appear at the point of delivery of public supplies.

We know now that it is not running water which purifies itself but still water; and upon this principle is based the first system of water purification used.

From the foregoing, it will be seen that in order to obtain a suitable public water supply from surface waters, except the same be drawn from uninhabited watersheds, it is essential that such supplies should be purified in such a manner as to remove the elements of existing danger.

The various systems of purification which have been devised for this purpose are as follows:

1. *Sedimentation.*
2. *Slow sand filtration.*
3. *Rapid mechanical filtration with coagulation.*
4. *Ozonation.*
5. *Sterilization, or disinfection.*

1. SEDIMENTATION

Sedimentation is based, as I have already intimated, upon the principle that still water will purify itself. This was recognized, to a certain degree, in the civilizations of ancient Babylon and Egypt, the object being to remove suspended matters from waters otherwise unfit for public use. Of course, no knowledge of the sanitary effects of the process existed. The ancient Egyptians, by this means,

were able to convert the muddy waters of the Nile into public supplies agreeable to the eye and taste. The factors which enter into this process are time, sunlight, oxidation and gravity. Of these, *time* is the most important, because by it opportunity is given to the other factors to perform their functions. Therefore it is necessary that the reservoirs in which the process takes place should be of sufficient capacity to allow for a period of not less than two weeks' storage, and in many instances a much longer time is necessary.

The effect of sunlight is more rapid in its action than is that of the other factors. Direct sunlight will kill bacteria rapidly. This action, however, can only be effective upon bacteria at or very near the surface of the water. Below at the most 6 inches from the surface it is ineffectual.

The process of oxidation in such reservoirs takes place under rather favorable circumstances, requiring only the element of time to secure satisfactory results.

The specific gravity of the bacteria is slightly greater than that of water. The result is that they gradually sink, and if sufficient time be allowed, will finally reach the bottom of the reservoir, where they either remain quiescent, or die, owing to their unfavorable environment, or are devoured by the infusoria and other animals of low type. Nor are the bacteria dependent upon their own specific gravity in thus reaching the bottom of the reservoir, but a large proportion of them are carried down by other suspended matter of a specific gravity greater than their own.

The result of the process is, that the water drawn from such reservoirs is practically free of turbidity, its color is diminished to a certain degree by the bleaching effect of sunlight and the oxidation of the coloring matters, its organic matters are more or less oxidized and its bacterial content is very much diminished. Under favorable conditions, as satisfactory results may be obtained by this process as by the process of filtration. As I have already stated, however, time is the most important factor

2. SLOW SAND FILTRATION

The second process to be used was that of slow sand filtration. This process, so far as known, was first put into practical operation by the Chelsea water company, of London, in the year 1829. It is similar in its phenomena to the natural filtration of ground waters

through the soil. It is simply an attempt to imitate artifically such process. Approximately, it means a bed of sand and gravel, retained by walls of some sort, varying in depth from two to five feet and underdrained. The raw water is admitted to the surface of said bed, filters through said sand and gravel, and is delivered by said under drains to a well or reservoir. The object for which it was first used was the removal of turbidity, the science of bacteriology not then being recognized or understood. It was looked upon simply as a strainer and it was found that it answered that purpose satisfactorily. Other filters were built in various places, which also gave satisfactory results.

In the year 1866, during the prevalence of a severe epidemic of cholera in London, it was found that those using filtered water suffered to a far less extent than did those using unfiltered water. This was so marked that the advanced scientists of the day formed the opinion that in some way the filter had sanitary value, although in just what way this value was obtained was unknown.

With the development of bacteriology and the isolation of various germs, both pathogenic and nonpathogenic, the science of slow sand filtration has become known, recognized and proven. It is known now that the straining action of the sand, from a sanitary point of view, is of but little importance, the bacteria being so small that they would readily and rapidly pass through the interstices of the finest sand used for the purpose. It has been found, however, that when water is applied to the surface of the sand, a deposit is rapidly formed upon the surface of that sand. This deposit is composed of living and dead bacteria, broken down organic matter, etc. It forms a carpet, which has been called by the Germans the smutzdek. Here the process of splitting up of organic matter into its nitrogenous and carbonaceous elements is constantly going on. The carbons are given off as carbon dioxides and other gases and the nitrogenous matters are converted into nitrous and nitric acids which unite with the bases in the water, forming nitrites and nitrates, which are simply harmless products of bacterial action. It also acts as a very thin strainer, intercepting the germs, most of which perish through unfavorable environment or the competition of other germs more virile and to whom the environment is not so unfavorable.

It is fortunate for the human race that the pathogenic germs carried by water are in such an environment more unfavorably situated than are many of the harmless varieties, so that they perish early in the struggle. The germs that are left live in the smutzdek,

or accidentally pass through the filter, are of the hardier water and soil groups, non-pathogenic and therefore of no interest to the sanitarian. It is a good illustration of the doctrine of the survival of the fittest.

After a certain time, this smutzdek becomes so thick that the water cannot pass through it rapidly enough for economic purposes. It is necessary then to clean the filter, by scraping off the upper quarter inch or so of the surface. When this is done the water is again applied, the first water passed through in the absence of the smutzdek not being fit for the purposes of public supply is therefore wasted, and the process of the formation of the smutzdek goes on as before.

The amount of water filtered, per acre, varies, as a rule, from one to three million gallons per day.

The chief objections to the system are the large area of ground required, the expense of construction, the liability to certain areas becoming clogged, to cracks developing in the sand, and to water getting into the underdrains with improper filtration, between the walls and the sandbed proper. It is also necessary, in the case of very turbid waters, in order to prevent clogging and therefore too frequent cleaning, to settle the water before application to the filters.

Although the system has given excellent results, still it is my opinion that its day is past. I believe that today we can obtain better results, much more cheaply and with greater certainty.

3. RAPID MECHANICAL FILTRATION WITH COAGULATION

This system, which is the so-called American system, was originally an attempt to secure the results obtained by slow sand filtration much more rapidly, on much less area, and more cheaply; its object in the first place being to clarify the water. It was first put upon a scientific basis in the year 1893 by Mr. E. B. Weston of Providence, R. I. Far greater advances with it, on scientific lines, were made by Mr. George W. Fuller, at Louisville and Cincinnati, and by Mr. Allen Hazen at Lorraine, Ohio, and Pittsburgh, Pa. The first really scientific plant constructed was that of the East Jersey Water Company, at Little Falls, N. J., in the year 1902.

It has been found that by this system practically the same results, from a bacteriological standpoint, can be obtained as by means of slow sand filtration. It requires very much less area; the rates of filtration are very much higher, running from 120 million gallons or

more per acre per 24 hours, and the cost of installation is decidedly less. The cost of operation and maintenance in a properly managed plant is about the same as that of slow sand filtration.

This system, unlike slow sand filtration, is not a bacteriological process, it being a purely mechanical and chemical one. Speaking approximately, the plant consists, first, of a coagulation basin, a series of small filters, usually of a size 24 by 15 feet, containing from $2\frac{1}{2}$ to 4 feet of gravel and sand, with a system of underdraining which delivers the filtered water to a well or reservoir. Before the water enters the coagulation basin, there is applied to it from $\frac{1}{2}$ to 5 grains, per gallon, of coagulant, usually sulphate of alumina. When sulphate of alumina is added to water, certain chemical reactions take place whereby the hydrate of alumina and sulphuric acid are formed. The sulphuric acid at once drives away from its bases the weaker carbonic acid and forms sulphates. For this reaction to take place it is necessary for the water to be sufficiently alkaline, either naturally or by the addition to it of some substance such as soda ash. The hydrate of alumina is a flocculent, gelatinous mass, permeating the water and sinking for the most part to the bottom of the coagulation basin, carrying with it suspended matters, including bacteria. After the water has been sufficiently coagulated in the coagulation basin it is then admitted to the filters and what is left of the hydrate of alumina and suspended matters are deposited upon the surface of the filter beds, in this way forming a smutzdek, although practically no bacteriological action takes place therein.

When the economic efficiency of a filter is interfered with by these deposits, both upon the surface and extending down into the sand, the filter is artificially washed and again put into use.

Certain changes take place in the coagulated and filtered water. The hardness is slightly increased by reason of the sulphates that are formed, as is also the free carbonic acid by its liberation due to its being driven from its bases by the sulphuric acid. These changes, however, are so slight as to be practically negligible.

This system is the popular one in this country, there being about 600 plants to less than 20 slow sand filtration plants. In Europe, however, slow sand filtration still maintains its standing, although quite a number of mechanical plants are in operation there. I believe that this system will be the one for the future, where filtration is needed, either alone or in conjunction with another process.

4. OZONATION

Much time, thought and money have been expended in an attempt to make ozone a practical means for the purification of water supplies. If this could be accomplished, unquestionably a great step in advance would be taken. It is possible in the laboratory, or on a small scale, but to the best of the writer's knowledge and belief, no means have yet been devised of applying it practically upon a large scale. I am aware of the claims made for the plant in connection with a part of the Paris water supply, but I still hold to my opinion as expressed. There are two chief difficulties to be overcome; one, the interruptions to the process of production of ozone, thereby allowing untreated water to enter the supply, and the other is to successfully apply the ozone to the water. Ozone does not dissolve in water but must be brought into contact with its various particles. This, with a large body of water to be treated, is very difficult if not impossible of accomplishment, so that again, in this way, untreated water reaches the public supply. It may be that sometime in the future human genius and ingenuity may overcome these difficulties, but I cannot see any indication of it at the present time.

5. STERILIZATION OR DISINFECTION

The latest development in the purification of water is by means of a system which is called sterilization or disinfection. As used at the present time in many cities of this country and in some in Europe and Asia, it is accomplished by the addition to the water of minute quantities of oxy-chloride of lime, or what is commercially known as "bleaching powder." The same results may be accomplished by the use of electrolytic salt solution. These results, however, are not as certain. There is no cell entirely satisfactory to be obtained, and the expense, unless free water power is available, is much greater.

The sterilizing effects of the hypochlorite of lime and soda have long been known and both have been used as general sterilizing agents for vaults, streets, yards, sewage, etc., for many years. Electrolytic solutions of sea water or salt have been used at Worthing, England; Nice, France, and at Poplar, England, for general disinfecting purposes, including street watering; for application to sewerage effluents at Maidenhead, England; by Rideal, for application to sewerage effluents at Guilford, England, and by Woolf for the disinfection of sewerage effluents at Brewsters, N. Y., and for general disinfecting purposes at Havana and Vera Cruz.

Solutions of bleach have been used for the disinfection of sewage or sewerage effluents on the river Brent in England, at Hertford, England, on the Hooghly River, India, at the Tittagurh installation near Calcutta, India, and at Guilford, England; by Schultz of Hamburg in connection with the effluents of hospital sewerage works; by Phelps at Baltimore, Md., and Red Bank, N. J.; by Pratt and Kimberley at Camp Perry and other points in Ohio, and by others at numerous places, with generally successful results.

Rather extensive experiments were made with solutions of bleach and soda in the early nineties, by Mauritz Traube, Alois Lode, Sickenberger, Kaufmann, Bassenger, Hunermann, Deiter and Ballner, their object being to obtain practically instantaneous sterilization or disinfection of water for the use of travelers or troops in the field. Their results, although not attaining the end sought, were successful in establishing the efficiency of both calcium and soda as disinfectants of water.

A solution of bleach was termporarily used by Sims Woodhead, at Maidstone, England, during the 1897 typhoid epidemic, for sterilizing the water supply.

During an outbreak of typhoid fever in Lincoln, England, in 1894–95, a solution of chloros (a commercial preparation of hypochlorite of soda) was used by Drs. Houston and McGowan, to sterilize the water going to the filters, and also to sterilize the reservoirs. In both these instances, good results were obtained.

In 1908 a solution of bleach was used by Johnson at the Union Stock Yards, Chicago, in connection with the filter plant, which was designed to supply drinking water for the cattle at the yards, the raw water being practically sewage. The results were satisfactory. The first time, however, that this process was used as a continuous method of water purification was by the writer at the Boonton, N. J., reservoir of the Jersey City Water Supply, said plant being put into operation on September 26, 1908. Since that time the writer has installed many plants throughout the country and many others have been installed.

The Boonton Reservoir has a capacity of 8500 million gallons. The draft of Jersey City is from 40 to 45 million gallons per day. The water as deliverd was aesthetically satisfactory. The color and turbidity were low and it was agreeable to the eye and taste. The process of sedimentation in the reservoir gave most satisfactory results, most of the time the reduction in the bacterial count being over 98.5 per cent. There were certain periods, however, namely, in

times of flood, or after very heavy rains, when the water seemed to flow too quickly from the inlet of the reservior (which is situated at the side and not at the head of the reservoir) to the intake to the conduit, with the result that the bacterial count increased materially and the B. coli were too often present in the water as delivered at Jersey City.

It was to correct this condition of affairs, occurring perhaps half a dozen times in the course of a year, that this sterilization plant was installed.

In the writer's study of the subject, and the study of the various experts whom he called in to assist him, certain facts were determined which, up to that time, have not been generally recognized or known. We determined as follows:

1. That bleach on being added to water ceases to be bleach, and therefore that criticisms which had been hitherto applied to such addition were without foundation.

2. That on the addition of bleach to water the loosely formed combination forming the bleach splits up into chloride of calcium and hypochlorite of calcium. The chloride of calcium being inert, the hypochlorite acts upon the carbonic acid in the water, either free or half-bound, splits up into carbonate of calcium and hypochlorous acid, the chemical symbol for which is HClO. The hypochlorous acid in the presence of oxidizable matter gives off its oxygen, O; hydrochloric acid, HCl, being left. The hydrochloric acid then drives off the weaker carbonic acid and unites with the calcium, forming chloride of calcium, the hydrogen being given off as a gas.

3. That the process was wholly an oxidizing one, the work being done entirely by the oxygen (the atom O) set free from the hypochlorous acid in the presence of oxidizable matter.

We have used during our investigation the term "Potential Oxygen" as expressing its factor of power. When set free it is really nascent or atomic oxygen, and is in its most active state, entirely different from the oxygen normally present in the water.

4. That no free hypochlorite or hypochlorous acid would be left in the treated water in the presence of oxidizable matter. It is true that at times in the treated water at Jersey City we have been able to get the reaction for so-called available chlorine, according to the method of Wagner as modified by Schultz, there being always oxidizable matter present in such water, and it has been a matter of a good deal of discussion as to the true explanation of this. In

my opinion, however, the matter has been definitely settled by the experiments and findings of Prof. Franklin C. Robinson of Bowdoin College, who first found such reaction in untreated water from the Boonton Reservoir, and afterwards in over seventy-five natural waters. It is but natural then to conclude, that this test for so-called available chlorine is simply a test for an oxidizing agent present in the water, be that what it may.

5. That any of the atomic oxygen left after the first explosion, by which the more easily oxidizable substances are destroyed, unites with those not so easily oxidizable and more slowly accomplishes the same results.

6. That no free chlorine could possibly exist in the treated water, the existence of free chlorine being impossible in an alkaline solution.

Dr. Heulett, Professor of Electro-Physical Chemistry of Princeton University, after most elaborate study upon the subject, determined that; first, no free chlorine could exist in the presence of organic matter; second, that if it did exist, with the dose that we were using it could only exist in the proportion of one part in 6.4 trillion parts, on which basis it would take many thousand years for a person drinking this water to obtain one medicinal dose.

7. That there could be no material change in the quality of the water after treatment, such as would in any way interfere with its use for potable and manufacturing purposes.

8. That it could be in no way materially affect piping, fixtures, etc.

The method of application of the bleach is approximately as follows:

There is first the emulsion tank in which the proper amount of bleach, by weight, to be added to the given amount of water, is made into a thick paste, and then emptied into the mixing tank. The water supply is then turned on and mechanical stirrers are set in motion. The outlet of this tank is near the top, so that when the solution reaches to that point it overflows into what are called solution tanks, which likewise contain mechanical stirrers. From the solution tanks, the solution is pumped, or flows by gravity, to the orifice tanks, and it is by means of the orifice tanks that the proper amount of solution is admitted to the given quantity of water.

The active principle, or rather the potential oxygen that is produced seems to have a selective action upon bacteria, and the greater part of such action seems to be almost instantaneous. It is true, that if all the potential oxygen be not used up in this first explosion,

what is left unites with organic matter and forms oxidizing agents, which act more slowly.

That which has been more surprising to the writer than any other one thing in connection with the process, has been the minute doses which will accomplish the purpose. He has never used, except experimentally at first, more than 0.45 parts per million available chlorine. This amount he has used at Omaha, Neb., where the raw water count in the Missouri River runs anywhere from 20,000 to 250,000 or more bacteria per cubic centimeter. Usually he uses from 0.2 to 0.3 parts per million available chlorine, and except under exceptional circumstances these doses are sufficient to accomplish the desired results.

These results are certainly phenomenal. In raw water, with counts running anywhere from thousands to hundreds of thousands of bacteria per cubic centimeter, the results obtained are either sterile or counts running from 2 and 3 to less than 50.

The bacteria which survive are mostly spore bearers, with a few of the hardiest water and soil bacteria. The colon is very rarely found, and then only in relatively large proportions of water. I believe when they are found, they have been enveloped by other matters in some such way as to make it impossible for the potential oxygen to reach them. It must be remembered too, in this connection, that B. coli are sometimes found in the effluent of all filtered waters, whether they be slow sand or rapid mechanical filters. Certainly they will be far less frequent after this treatment than after filtration. Their presence is simply accidental, and in consideration of the system in comparison with others may be ignored.

As a part of the investigation made in connection with the installation of the Boonton plant, many laboratory experiments were made by Professors Mason, Kinnicutt, Park, Wesbrook, Dr. McLaughlin and Mr. Johnson, as to the effect of the treatment upon the colon and typhoid organisms. These organisms were introduced into sterile waters, and waters containing organic matter in large quantities, and the solution in varying doses applied. The results of all the observers were identical. These organisms were destroyed almost at once, although present in far greater proportion than they could possibly be under natural conditions.

In no plant with which the writer has been connected has he ever experienced any taste or odors. The one fault which I have been able to discover in the system, however, is that its installation and use seems so simple that it has been installed and operated in

various places by inexperienced persons, and through faults of construction or of operation satisfactory results have not always been obtained and unpleasant tastes and odors have been experienced. It is a simple process and easy of application. At the same time, there are certain fundamental principles which must be understood and carried out in order to obtain the desired results. For instance, a laboratory in connection with the plant is absolutely essential. In most of the places where unfortunate results have been obtained such laboratory has not existed in connection with the plant, or too infrequent examinations have been made. It is also necessary, by experiment, to find out the proper dose for any given water. The universal tendency of the inexperienced manager or superintendent is to use entirely too much of the agent and thereby cause the development of unpleasant tastes and odors.

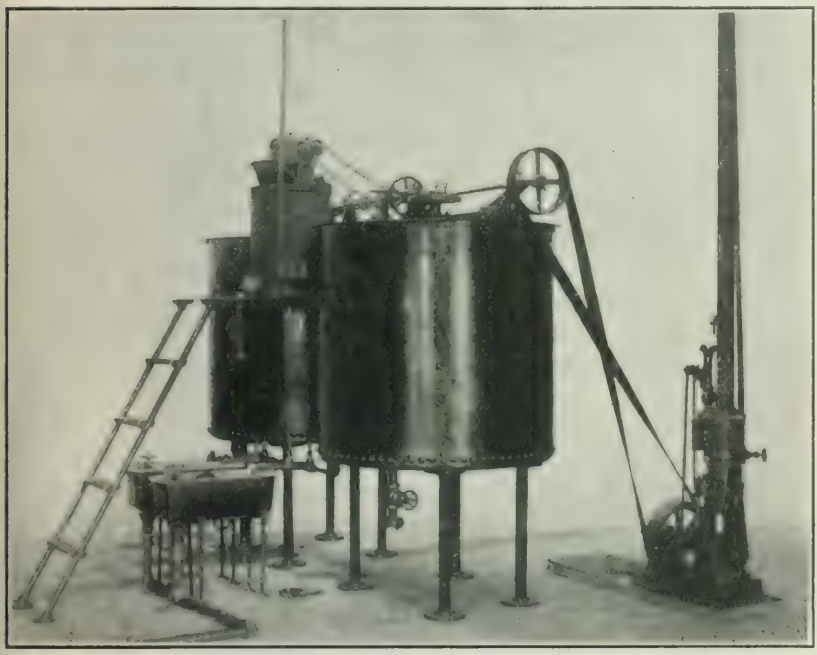
After all, it is a machine, as are both the slow and the rapid filters, and should be installed and operated by a person properly educated and trained for the purpose.

It cannot be claimed that this system is applicable to all waters. What it does is to destroy the bacteria, especially the pathogenic bacteria. For hygienic purposes, therefore, it is the most available, the cheapest, the simplest and the most effective system known. The aesthetic side of a water supply, however, must be considered, and sterilization does not remove turbidity or color. It will destroy certain algae and remove the bad odors resulting from their presence; whether it will destroy all algous growths, or not, is unknown at the present time.

It is applicable in cases of emergency to any water. It is applicable alone to any water that is aesthetically satisfactory. It is a most valuable and even necessary adjunct to the other methods of purification. It is acknowledged today by the leading experts on the purification of water, that it should form a part of every system of water purification. It makes their hygienic results more certain. It will allow of more rapid rates in both slow and rapid filtration, thereby diminishing the initial outlay. In the case of rapid mechanical filtration, it will also diminish very much the amount of sulphate of alumina necessary to obtain the desired results, thereby materially diminishing the cost of operation. Where supplies are drawn from large lakes or reservoirs, affording ample opportunity for sedimentation, this process as a supplement makes the system all that can be desired. Where the water is of such a character that filtration is necessary, then this system, in conjunc-

tion with rapid mechanical filtration, seems to be the process indicated. Of course, it can be used in connection with slow sand filtration, but it seems to the writer that it would be very foolish, with what we know today, to construct a slow sand system at the expense involved, when as good or even better results can be obtained by rapid mechanical filtration in conjunction with sterilization, at very much less expense.

The time is coming when every intelligent community will demand that it be supplied with water suitable for its needs. With the



PORTABLE STERILIZATION PLANT

growth of cities and towns, the more and more frequent installation of sewers, either emptying directly into our lakes and rivers, or emptying into them a more or less purified effluent from sewage disposal works, the waters of such lakes and rivers have become and are becoming more and more unsuitable as public supplies. The science of sewage purification has not yet reached a point of development which renders it perfectly safe to deposit even effluents from disposal works into waters from which public supplies are drawn. It seems therefore that the first necessity is the purification of the water

supply; the purification of sewage can come later. Both are necessary, but the first is vastly the most important.

The New Jersey General Security Company has recently had constructed a portable sterilization plant, for emergency use, capable of treating almost any supply of water. This plant can be put into operation within two hours after its arrival upon the ground. This apparatus is permanent and durable, and is equipped with all the accessories and appurtenances necessary for the most effective work. The idea is, if call be made, to ship it by fast freight, or express, its weight being about two tons. A portable laboratory accompanies it, with skilled operator. Its capacity is dependent entirely upon the labor employed, so that it is adaptable not only to small supplies but also to those of considerable size. A cut of the apparatus is herewith exhibited.

The sterilization system therefore marks a great step in advance in the purification of public water supplies; first, on account of its cheapness, which brings it within the reach of those who could not afford the great expense involved in filtration or sedimentation; second, its simplicity; third, its efficiency and indeed certainty. There is a most promising future before it, and there can be no doubt that the proper utilization of it can but add materially to the sum totals of human life, health and happiness.

DISCUSSION

Dr. Bartow: It appears to me that Dr. Leal has done well to emphasize the necessity for control of this method of water purification. That might also be extended to any treatment plan by which the same result could be accomplished. In regard to what he said of the different treatment for various waters, we have made a few experiments with distilled water, well water, Mississippi river water, to determine the amount of bleach which might be used, and found it to be inversely proportional to the order in which I have named them. We can use least with distilled water, more with well water, and the most with filtered water which contains the largest amount of organic matter. I was interested in his emergency plant, and will call attention to the fact that the Minnesota State Board of Health has recommended an emergency plant for use in the State of Minnesota, and it has I understand been used with effect in a number of instances.

MR. BASS: With reference to what Dr. Bartow said about the portable emergency plant used in Minnesota, I might say that I have had something to do with the development of that plant, so it probably would be of interest if I should mention a few of its distinctive features. One advantage it has for the locality is that it is much less expensive and therefore better adapted to the poorer and smaller western communities than the one Dr. Leal has shown on the photograph which he exhibited here. It might be said to be home-made. It is made of two whisky barrels and one keg. The principal difference in its operation and that of the one shown in the photograph is in the method of controlling the administration of the liquid. The solution is allowed to flow from a mixing barrel into an air-tight barrel, fitted with an air vent. When the latter is full, the flow is stopped and the vent closed. From the air-tight barrel, the solution flows to the orifice tank in which a constant level is maintained in the following manner. There are two pipes leading from the air-tight barrel to the orifice tank, one to convey the solution from the bottom and one for air, from the top. As the water level reaches the top of the orifice tank it meets the lower end of the pipe leading from the top of the barrel and the air supply into the air-tight barrel is cut off and the flow of water is stopped; then as the water flows from the orifice tank the level therein drops slowly below the pipe from the top of the air-tight barrel, letting a little more air in and allowing a little more solution to flow out through the bottom. The level in the orifice tank immediately rises and by closing the lower end of the pipe from the top of the air-tight barrel cuts off the air supply and throttling the flow in that manner maintaining practically a constant level. As the orifice in the orifice tank is at a certain known distance from the surface the flow is constant and is maintained without the use of any moving parts. I might say that the whole cost of this emergency hypochlorite plant which we have used to treat about a million gallons a day more or less, is about $47. The weight of the entire plant including fittings is about 350 pounds.

METHODS OF KEEPING RECORDS OF IMPROVEMENTS TO ESTABLISHED WATER WORKS PLANTS

By Charles Carroll Brown

This is a large subject, too large to cover in one paper, and so this paper will be restricted to the statement of a few of the underlying principles, some suggestions of methods of classifying and recording items and some examples of the practical application of these principles and methods.

The word "improvements" in the title to this paper is intended to cover new construction of extensions and enlargements, replacement of outgrown or out-of-date materials, apparatus, machinery or structures, and repairs and maintenance of existing structures.

My interest in the subject is largely due to the difficulties in the way of determining the value of a plant for purposes, of sale, purchase, or determining equitable rates.

The records are naturally classified into records of disbursements, records of the stock pile and records of construction cost.

1. The accompanying standard form of "Cash Disbursements and Voucher Record" separates the expenditures for construction, general expense and fixed charges, and maintenance and repairs, and would be sufficient for the financial records were it always possible to distribute the items in vouchers at once to the proper columns under the above named general headings. But some of the new material and apparatus purchased is put into stock and is drawn from as required, so that the distribution of items, if made accurately, must be made when the material is drawn from stock. When accurate records are required, there must, therefore, be some method of taking care of the stock account and making this supplementary distribution before the closing of the books for the annual report.

In a small plant it is possible to determine, with very close approximation to accuracy, the probable destination of each item in each voucher and to make the distribution in books made according to the accompanying form, where the voucher totals are entered in

the right hand column on the left hand page, so that this form is ample and sufficient for such small plants.

In larger plants where a considerable stock account is carried, the distribution must be made later, as stated, and the method of making this distribution and of keeping the records thereof is the subject of this discussion, which will be confined to a few of the items, perhaps enough to show the principles, and give indications of the methods of applying them, that may be devised.

All purchases of materials and apparatus may be carried to a stock account, and all labor on repairs and handling of materials may be charged to the same account and the distribution may be made under the heading of the stock account. This method of keeping the records might almost entirely eliminate the "Construction" section of the accompanying forms, and some accountants may prefer this method of treating the vouchers.

A large proportion of the purchases may be assigned immediately to the proper division, whether "Construction" or "Maintenance and Repairs," and only such portions as go to stock need be charged to the "Stock" account. Also, the pay rolls and labor accounts can often be so made up that the labor of handling materials and apparatus into and out of the stock piles can be charged accurately to the "Stock" account. This latter distribution is not always easy to make, for it requires a detailed record of the distribution of time of men, for which few water works superintendents have prepared proper forms. In such cases arbitrary rules for charging such labor and materials are sometimes made.

The blank columns between the "Vouchers" columns and the "Construction" columns on the left hand page of the accompanying form may be used for this "Stock" account, using only one column therefor, or using two, one for materials and the other for labor, as may be preferred.

2. A special stock account will then be kept, to which these items will be charged, and whenever anything is taken from stock it can be credited to the stock account and distributed to "Construction" or "Maintenance and Repairs" in columns with the same headings as those in the "Cash Disbursements and Voucher Record." When the books are closed before the annual report, the stock account can be closed first, and the footings of these columns can be transferred to the corresponding columns in the "Cash Disbursements and Voucher Record." The totals of these columns will then represent the materials, apparatus and labor actually used during

CASH DISBURSEMENTS

CONSTRUCTION

VOUCHERS

No.	Date	Voucher	Distribution	Amount	To Whom Paid
1	1905 Jan 31	22 50			M. J. Drummond
2		23 50			Eddy Valve Co.
3					Bumpless Lever Foundry
4					
5				7/3 46	Geo. Thornton Agency
6				7/3 47	Bell Telephone Co.
7				7/3 48	Geo. Thornton Agency
8				7/3 49	Thompson Belt Co.
9				7/5 50	Hooley Mfg Co.
10				7/7 51	Western Foundry Co.
11				7/9 52	Geo. Thornton Agency
12				7/9 53	Central Foundry Co.
13				7/10 54	Journal Printing Co.
14				7/10 55	Municipal Engineering Co.
	1905 Jan 31	22 50			

AND VOUCHER RECORD

16

GENERAL EXPENSE AND FIXED CHARGES

MAINTENANCE AND REPAIRS

Pay Roll	Stationery and Printing	Office Supplies and Expenses	Insurance	Miscellaneous	Total	Remarks
		95				
26		6	42			Pay Roll
	2					Postage
26		10	42	120		Pay Roll & Meal
	68					Bill of Sale
112 10	72	16	40	120		

the year. If stock began with zero and ended with zero, the sums of the distribution columns would equal the total of the "Vouchers" column. Ordinarily, however, this balance cannot be made without bringing in the balances from the stock account, and the "Cash Disbursements and Voucher Record" must have a trial balance before the column footings from the "Stock" account are transferred to it. The one or two "Stock" columns in the "Cash Disbursements and Voucher Record" must, of course, be included to produce the balance.

3. An engineer's record of materials and labor used and expended on each job of construction and repairs is very desirable. It can hardly be compared with or closed into the "Cash Disbursements and Voucher Record." Neither can it be directly connected with the "Stock" account, unless that account includes all purchases and all labor on construction and repairs. But the accounts can be so classified that proper balances can be made and the entries and distributions thoroughly checked.

In showing the method of making the records of improvements, it is necessary to consider the "Cash Disbursements and Voucher Record," the "Stock" account and the engineer's records, the latter often being the records of the foreman in charge of the job in the smaller plants, in which the superintendent also acts as engineer.

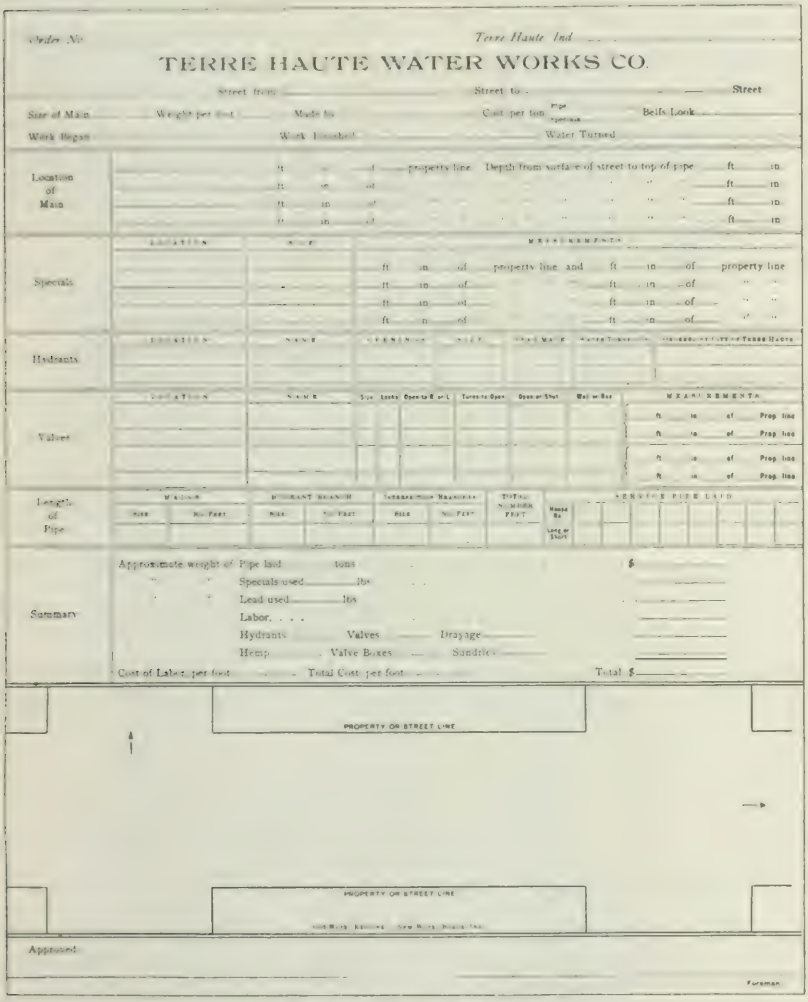
I am indebted to a paper on "Pipe System Records" presented to the Indiana Engineering Society by Dow R. Gwinn, manager of the water works at Terre Haute, Ind., and to Mr. Gwinn himself for much of the material presented in exemplification of the operation of the plan above proposed and for most of the forms of record discussed.

For either large or small stock accounts the card system of keeping records will be found most convenient. The following form of card is suggested for keeping account of the material passing through the stock account and not directly to a construction job, the headings being modified from those used by Mr. Gwinn to fit them for use with the record book above shown:

First Column—Number of Voucher (Corresponding to that given in the "Cash Disbursements and Voucher Record").—It may be necessary to enter this number after the date of receipt of the material in stock, if the voucher is entered in the book after the stock is received.

Second Column—Date of Receipt.—This date is the date of receipt of the material in stock and may differ from the date of the voucher of corresponding number.

Third Column—Date of Removal.—This date is the date the material is removed from stock and charged to some particular item of construction, renewal or repair. These two date columns might be



RECORD OF PIPE LAYING

combined in one, but it is easier to catch the differences in the fourth column if the two date columns are carefully used.

Fourth Column.—This column gives, opposite the voucher number and date of receipt in first and second columns, such information about the materials received as is wanted. Ordinarily this

information would be greatly abbreviated, using a standard set of abbreviations, and this column, a wide one, taking at least half to three-quarters of the width of the card, would tell the maker of the material, the place at which it was delivered and, if all the materials purchased pass through the stock account, the statement of the account to which it should be charged, whether new construction, maintenance and repair, or reconstruction.

Opposite the date removed, given in the third column, there would be entered in the fourth column the description of the material taken from stock and the place or job to which delivered and to be charged, and a statement of whether it is construction, maintenance and repair, or reconstruction.

Fifth Column.—This, a narrow one, would give the number of pieces, pounds, gallons, etc., received or removed.

The *sixth column* would give the number in stock, beginning on the first line with the amount brought forward and adding or subtracting the amounts in the fifth column, according to whether they were received into or removed from stock.

If the material, such as pipe, is counted in lengths and paid for in pounds or tons, the seventh and eighth columns may be added, one giving the weights and the other the cost, into or out of stock.

Thus the fifth and sixth columns would give the number of pieces, lengths of pipe, etc., the seventh would give either the total weight of the number given on the same line in the fifth column and the eighth the total cost, or the seventh column might give the average weight and the eighth the price per unit. The latter is probably the more convenient.

One of these cards will be made for each separate item in stock; one for each size of cast-iron pipe, for each size of wrought iron pipe, etc.; one for each size and each combination of sizes of crosses, tees, reducers, etc.; one each for lead, leadite, oakum, cement and each other item of supplies.

Mr. Gwinn has a very complete form for reports of engineer or foreman in charge of each job of work, which he styles "Record of Pipe Laying." It covers both sides of a card $10\frac{1}{8}$ inches wide by $12\frac{1}{2}$ inches long, which is folded in thirds for convenience in carrying by the foreman. Copy of this card is included herewith. As much as possible of the information to be entered on the card is written into it on the typewriter before it is given to the foreman, so that the writing to be done by him can be reduced to a minimum.

In a sample card kindly copied by Mr. Gwinn from an actual office record, the information supplied by the office includes the location, size of main, weight per foot, manufacturer, cost of pipe per ton and of specials per pound, position of bells, year, location of main, except actual figures of distance from line noted and depth, locations of tees, hydrants and valves except the measurements, and a sketch showing the existing main, names of streets and points of compass. The foreman inserts the measurements, the description of valve, the lengths and sizes of pipe, the date water was turned

Water Works

RECORD
OF
PIPE LAYING

REMARKS

on, and adds the new work to the sketch, with measurements and sizes. All of this side of the blank is copied on sheets of a loose-leaf record book, and these sheets are filed in a definite order, so that they can be easily found by one familiar with the geography of the city.

The foremen's reports, themselves, are put in special envelopes, with all other data collected with reference to the job, and are filed in the same order as the leaves in the record book.

On the back of the sheet appears under "Remarks," in the sample under description, a detailed description of the street grade as a

guide for the excavation, being filled in at the office. The foreman enters on proper lines the number of pounds of lead or leadite used, the number of joints made in each size of pipe, the number of hours of each kind of labor, the charge for hauling by outside party and for company's teams, the number of lengths of pipe used and the number and size of specials used, such as tees, valves, valve boxes, plugs, hydrants, etc.

This record seems to be complete enough so that the office force can check up the stock accounts by comparing these foremen's reports with the cards on which the stock account is kept and with the vouchers for materials and labor. The totals of company's labor can be compared with the pay rolls, for further check. These all make it possible to distribute the items from stock to the proper columns, and to fill any deficiencies in information as to distribution of labor items.

For the plants for which the "Cash Disbursements and Voucher Record" is sufficiently detailed, the summary of the stock account thus checked and amplified by comparison with the reports of construction, can be reduced to a series of items corresponding with the headings of the columns in the "Cash Disbursements and Voucher Record," and at the end of the year the sums of the columns can be taken and these sums transferred to that record and added to its totals, as suggested early in this paper. These totals will then contain all the transactions for the year, although the final sums will not check with the total of the voucher column, unless, as above stated, the stock account stands at the end of the year exactly as it did at the beginning.

There is one item which is not covered by the above description. In case pipe and specials are taken up and returned to stock for future use elsewhere, the foreman's reports should show such facts and the stock account should show the receipt of such material. This material would not appear in the voucher record, since nothing has been paid for it, unless possibly the cost of handling it should be charged to it. In any event, the cost would be small and would reduce the average cost of that class of material in stock. When used, the proper account must be taken of these facts, according to the policy of the managers of the plant.

It may be profitable to discuss the question of policy to some extent. The main purpose of keeping the records described is to determine the actual cost of the construction and maintenance of the plant. It is sometimes difficult to determine whether a certain

charge shall be made to construction or to maintenance, and how to manage the credits and charges when a transfer is made from one part of the system to another, whereby one part is discontinued or replaced and another part is repaired or an addition is made, using the materials from the discontinued part. This brings in the question of the present value of the plant, through a consideration of the depreciation of the part thus used a second time. If the object of keeping the records is kept clearly in mind at all times, these difficulties will be largely removed.

Assuming perfect judgment and supervision in design, construction and maintenance, the actual value of a plant at any date is its first cost, plus the additions and minus its depreciation. The first two items can be determined exactly by means of the system of records described. The latter cannot be determined exactly, and we must make as close approximations thereto as may be possible. We are interested particularly at this moment in the treatment of the re-use of material taken out of a plant and used later in another part thereof, that the actual cost and actual value may be maintained and no fictitious addition or subtraction be made.

For example, an 8 by 6 cross is put into a line and charged to the cost of that line. It remains in place for ten years and for some good reason is then removed from the line. The labor cost of removal is possibly charged to new construction in connection with a new branch put in, or possibly to maintenance and repairs in case the removal was in connection with the repair of the original line. The cross is then put in stock, where it remains for say three years. It is then put into a new line.

If the total cost of the system is the important consideration, the voucher record will show nothing but the cost of taking out and re-locating the cross, doubtless concealed in a construction or repair pay roll. The cross will be charged to stock and again credited to stock, and charged to the new line without any valuation.

This method of taking care of the case brings in chances for discrepancies, unless considerable care is exercised. Thus, in an inventory taken when the cross was in stock, it might easily be counted at full value if not at original cost. Again, a superintendent who keeps the full records of construction described above will hardly be satisfied with the report of cost of the new line, because it is less than the actual value by the value of the cross, and so will not compare with the cost of other lines without special explanation.

For the purpose of this record, therefore, the cross should be

charged at its value to the new line. This value is not its original cost, but its value after depreciation is charged off, either according to fixed rule or according to actual value as estimated from examination. If depreciation is properly charged off each year, the former method of determining the value will keep the closer to the book value of the plant. So far as the stock account is concerned, there is no difficulty, for the charge in and credit out will balance There will be less chance for discrepancy in the inventory. To avoid interference with the total value of the plant, it will be necessary to credit the line from which it was removed with the same value that is charged to the new line. This should be done for the benefit of the valuation of the plant as derived from the summary of the costs of the individual lines kept in the records described. For when a line is removed it is no longer of value, and the construction record of the line should show a credit to offset the original cost or the value at the time of removal, if depreciation has been charged off. When part of a line is removed, it is reduced in value by the value of that part of the line.

The form of engineer's or foreman's report is such that this question of depreciation need not be considered in detail in making up that record. The actual pieces, lengths, etc., are there recorded, with dates and such other information as may be valuable in determining actual cost or actual value. These latter computations are made in the office and can be made at leisure or when the occasion demands. More nearly accurate allowance for depreciation can be made if it is made on each section of the work, the rates of depreciation varying with the character of the construction.

It does not seem difficult, therefore, to provide in the blank books described, with some slight modifications, for entries in about the following order:

1. The voucher will be entered in its proper column in the "Disbursement and Voucher Record."

2. Its items will be distributed to the columns under "Construction," "General Expense and Fixed Charges" and "Maintenance and Repair," all items of materials and cost of handling them to be entered first in columns under "Stock" and then distributed either directly in the "Cash Disbursement and Voucher Record" or in supplementary "Stock Record" whenever the distribution of stock is actually made to "Construction" or "Maintenance and Repairs."

3. Enter the materials as received on the proper cards in the card record of materials in stock, and credit out as delivered on the job

the materials taken out of stock and put into the work. Enter and charge materials taken out of old construction and put into new in the same manner. Give with each entry, in the proper column, the source from which the material is received, its price, total cost, freight and handling charges and labor being separated if possible, data on which to estimate depreciation, in short all possible information about the material received; the place to which material is delivered, its cost, handling charge, source, price per unit paid or charged as the case may be, or average cost in case the exact cost of the particular piece of material cannot be exactly identified.

4. Enter on the engineer's or foreman's report of construction all data regarding amount of material used and kind, labor and item to which to charge it, dates, etc., as required on the form presented; also data regarding materials removed and returned to stock in full. Blank space may be left expressly for this or it may be entered under "Remarks," with proper note on the other side of the card.

5. In transferring the foreman's report to the record book, all the blanks due to lack of information or greater ease of computation in the office than in the field should be filled in and the actual cost of the job should be worked out completely before records are lost or memory becomes dim.

In the process of transferring the foreman's reports to the record book provided for them, the stock record can be checked, and in part at least the voucher record can be checked. The vouchers for the construction or repair will, of course, carry their distribution on the back and can therefore be entered directly in the "Cash Disbursement and Voucher Record."

The distribution of "Stock" if made separately on the supplementary "Stock Record" must, of course, be made in cash, as it is a distribution of vouchers or their equivalent, and these cash figures should check with the figures used in the computation of cost of construction of each job.

The annual summary of the "Stock Record" thus distributed may be transferred to the "Cash Disbursement and Voucher Record," to show the totals for the year if such supplementary record is kept.

This treatment of records makes it possible to draw a more definite line between construction items and maintenance and repair items. Materials are usually easy to charge to one of the two groups, but labor is not so easy, especially when that labor is used in re-constructing a line, part of which is truly new construction and part replacement of old structures worn out or outgrown. If, now,

the old material is charged back to stock, at its value at the time, or is written off entirely in case its value is zero, and the new material replacing it is charged at its value new, the increase in value of the plant due to the replacement is attributed to the line into which it is put, and thus gets into the plant, and the record shows the increase in value. The amount of depreciation allowed on the old material shows the amount of the new construction that should be paid for out of the depreciation fund which every plant should have. The remainder should be paid out of the fund for new construction. If the work done is not in any sense new construction, but is re-construction or repair of old structures, then the whole net expense would be charged to the depreciation fund. In other words, all new material which increases the first cost of the plant, *i. e.*, adds to its capacity or convenience of operation, should be charged to new construction, and all material which does not so add to the first cost, but simply restores the former ability of the plant to do the duty for which it is designed, should be charged to maintenance and repairs and paid for out of the funds provided for that purpose or to take care of depreciation, as the policy of the company regarding these funds directs.

Labor items are not so readily distributed, and numerous arbitrary rules have been devised to take care of them, for example, to charge the materials to new construction and the labor to maintenance and repairs, on the assumption that this will come near being equitable. If, however, the same principle is applied to labor that is applied to materials, the number of doubtful cases will be greatly reduced.

It is true that most of the new materials supplied in the doubtful cases will belong properly to new construction, and that most of the labor will belong properly to repairs, but consideration of the principle that what adds to the first value of the plant is new construction and what only restores that first value is repairs, will enable the superintendent to make the distribution of his labor account as easy as that of his material account.

To be sure, the foreman cannot always distribute the time of his men exactly between the two classes of items, but he can give some information about it, and the engineer, if he does it before the matter gets cold, can form a very good judgment of the proportionate distribution of the labor account on the particular job between the two classes of items.

More time is taken in the discussion of these peculiar items, because, while proportionately very small, they are very troublesome. The principle can be applied readily in the ordinary case and is usually properly followed. Only one or two classes of cases are suggested because they are used only as examples of the application of the principle. Each one can make his own decision regarding each such case which arises, if he will remember the principle and check up his decision to see whether it has been followed throughout.

DISCUSSION

Mr. Gwinn: I am very much obliged to Mr. Brown for having brought out the facts as he has. It is the system we have been using for some little time; but I did not appreciate its value until Mr. Brown came along and saw there was something good in it. I was simply working along the best way I knew how; but he has taken these forms and combined them with something else, and really perfected the system.

PUBLIC UTILITIES

By John C. Trautwine, Jr.

To those who are interested in watching the progress of socialism, two of the papers read at the New Orleans Convention of 1910 and printed in the *Proceedings* for that year, furnish much food for thought.

I refer to *A Coöperative Water Works Franchise*, by Mr. John W. Alvord, and *Municipal Ownership*, by Mr. Park Woodward.

Mr. Alvord says: "That the public is, and ought to be, a silent partner in the utility company, is now recognized, and it is an open question if the time has not already arrived when it should be more than a silent partner. Certainly, in new contracts and franchises, the question of the municipality becoming an active partner is being seriously considered." Mr. Woodward speaks of "our socialistic idea of government," and says: "There are few more attractive theories than municipal socialism."

A little more than a century ago, our industry was almost wholly individualistic. Even in the matter of public streets and roads, our forefathers had enjoyed hardly any of the great benefits which we of to-day have secured through socialistic coöperation. Public water supply was almost unknown in America. Individual wells and pumps were the rule, and these were very commonly located in the immediate vicinity of cesspools, with the result that our cities were repeatedly scourged with yellow fever and other waterborne diseases.

But the steam engine made its appearance, requiring, for its construction and operation, a degree of combination of capital and of labor which before had scarcely been thought of. Shortly after this, the steamboat and the railroad came into use, and the era of socialism was fairly launched. Its subsequent development has eclipsed everything previously experienced or dreamed of in the history of the race.

One by one, matters which had been regarded as proper subjects of private enterprise have come to be recognized in their true light of "public utilities;" and great corporations are vying with each

other, and with the state, in the transfer of business enterprise from private into public hands.

Rightly viewed, a great corporate enterprise, such as the Standard Oil Company, the Pennsylvania Railroad, or the United States Steel Corporation, is essentially a socialistic undertaking, as is the construction of the Panama Canal.

The difference is merely that, in the one case, the agents of the public are, as yet, permitted to take their compensation in the form of the *profits* which they can extort from the public (as did the king's tax-gatherers of old, to whom the tax-gathering was farmed out, upon a similar basis); whereas, in the other case, the public's agents are paid such *salaries* as the combined wisdom of the country finds a proper reward for their services.

And even this difference is to a large extent disappearing, when (as arranged by Mr. Alvord's coöperative scheme) the public becomes not merely a silent but an active partner in the enterprise (or the sole stockholder, as at Louisville), and when the corporations themselves come before the public, asking the public to control their operations and to determine the compensations to which they are entitled, as in the 1910 report of the American Telephone and Telegraph Company, in which the company says: "Public control or regulation of public service corporations by permanent commissions, has come, and come to stay. Governmental control should ensure to the public good service and fair rates."

In his recent testimony before a congressional committee, Judge Elbert Gary, head of the United States Steel Corporation, said "enforced publicity and governmental regulation, even of prices, must come eventually," and entered a plea for "a governmental department which could tell them *what they could charge* and what they could do."

When the public fixes rates, and controls operation, we are at the beginning of the end.

In all these discussions, much stress is laid upon the necessity of securing, to the private company, a "fair" return for its investments and its labors. Now any "fair" tribunal, passing upon this question, will bear in mind that the services of very eminent men can be secured, for the Presidency of the United States, for postmaster-generalships, and for the conduct of such work as the construction of the Panama Canal, for salaries of a few thousand dollars per year.

We are told that those who engage in large private enterprises are entitled to the princely rewards which they sometimes secure,

by reason of the great risk of ultimate loss, which attends all such enterprises; but as these enterprises come under the control of the public, they are given so great a degree of security that this plea falls to the ground.

Furthermore, in the past history of these undertakings, our captains of industry have earned large compensations by waging wars of competition against each other; but, under the new régime, competition (as pointed out in the report of the American Telephone and Telegraph Company) will have become a back number, and those in charge of public utility companies will be entitled to receive only such compensation as is paid to those who conduct these works in warfare against nature alone.

But, for the state to control prices, while leaving the question of wages to the tender mercies of the "proprietors," would be straining at gnats and swallowing camels. The "working people" and their families form a large majority of the persons composing the state; and the very life of the state requires that they be well fed, well housed, well clothed, well educated, and not over-worked. The state must therefore control wages, as well as prices. When it does so, the chance for "velvet," to those on the inside, will be so diminished that they will lose interest in the enterprises, and these will gravitate naturally into the hands of their real owners, the people.

Socialism has been laughed to scorn for seeking to abolish competition, "the life of trade" (and the death of the trader); but the American Telegraph and Telephone Company, in the report already quoted, assures us that:

> Effective, aggressive competition, and regulation and control are inconsistent with each other, and cannot be had at the same time.
>
> Control or regulation, to be effective, means publicity; it means semi-public discussion and consideration before action; it means deliberation, non-discrimination; it means everything which is the opposite of and inconsistent with effective competition.
>
> Competition—aggressive, effective competition—means *strife*, industrial warfare; it means contention; it oftentimes means taking advantage of, or resorting to, any means that the conscience of the contestants or the degree of the enforcement of the laws will permit. To make competition effective, great and uncontrolled latitude of action is necessary; action must be prompt and secret.
>
> Aggressive competition means duplication of plant and investment. The ultimate object of such competition is the possession of the field wholly or partially; therefore it means either ultimate combination on such basis and with such prices as will cover past losses, or it means loss of return on investment, and eventual loss of capital. However it results, all costs of aggressive,

uncontrolled competition are eventually borne, directly or indirectly, by the public.

Competition which is not aggressive presupposes coöperative action, understandings, agreements, which result in general uniformity or harmony of action, which, in fact, is not competition but is combination; unstable, but for the time effective.

In so far as socialism has been permitted to operate, it has abolished poverty. The so-called "poor man," of today, is immeasurably rich, as to water and light supply, streets, parks, postal facilities, and a multitude of other utilities, compared with the millionaire of a century ago.

Mr. Woodward says: "There are few more attractive theories than municipal socialism; but it may be also said in practice, they have generally proven failures."

For this he finds the reason (where we must all find it) in the impertinent interjection of so-called "politics" into our public affairs, but it is interesting and important to note that Mr. Woodward urges this argument of political corruption, not only against, but also in favor of, municipal ownership; for he says, "all large monopolies, who own public franchises, are the principal causes of corruption in municipal government, through their attempts to control legislation, to secure and keep their franchises, and to enlarge and increase their privileges, without regard to the public interests."

It is hardly necessary to observe that such corruption has its rise solely in the persistence of what remains to us of the individualistic method of doing business, which puts its premium upon unscrupulous self-seeking. Such corruption will have disappeared when socialism becomes complete.

As bearing upon this question of political corruption, there is much significance in Mr. Woodward's remark "that a municipality can borrow money at much less rate of interest than a private company." Why should it not? The enormous economy, incident to municipal socialism, and the fact that the entire community is back of the bonds, enable the municipality, in spite of its admitted load of graft, not only to stagger along, but to show a degree of prosperity and of credit unattainable by the private company.

More than twenty years ago, in his *Looking Backward*, describing, in imagined retrospect, the happenings of our own days, Edward Bellamy wrote:

The change had been long foreseen.—Popular sentiment, toward the great corporations and those identified with them, had ceased to be one of bitterness

as they came to realize their necessity as a link, a transition phase, in the evolution of the true industrial system. The movement toward the conduct of business by larger and larger combinations of capital, the tendency toward monopolies, which had been so desperately and vainly resisted, was recognized, at last, in its true significance, as a process which needed only to complete its logical evolution, to open a golden future to humanity. The most violent foes of the great private monopolies were now forced to recognize how invaluable and indispensable had been their office in educating the people up to the point of assuming control of their own business. By a series of object lessons, seen and studied by all men, the great corporations had taught the people an entirely new set of ideas on this subject. For many years they had seen syndicates handling revenues greater than those of states, and directing the labors of hundreds of thousands of men with an efficiency and economy unattainable in smaller operations. Thus it came about that, *thanks to the corporations themselves*, when it was proposed that the nation should assume their functions, the suggestion implied nothing which seemed impracticable, even to the timid. *Early in the last* (twentieth) *century*, the evolution was completed by the final consolidation of the entire capital of the nation.

And Bellamy seems not to have foreseen that, as the corporations grew and waxed strong, the state, if only in self-preservation, must keep pace with them in strength, and must also become, itself, their strongest competitor, rendering still simpler and more inevitable, the final consummation.

Mr. Woodward says: "It goes without saying that any enterprise in which the general public is directly interested should be owned and operated for their benefit."

What enterprise is there, and what enterprise can be conceived, in which the general public is *not* directly interested? We have come to think of the public as being directly interested in streets, in public parks, in sewage disposal, in water supply, in telegraph and telephone systems, in the post-office, in lines of communication; but is not the public at least as vitally interested in the baking of bread, in the slaughtering of cattle, in the bearing and rearing of children?

COMPRESSED AIR IN WATER WORKS CONSTRUCTION

By Alexander Milne

The use of compressed air as a mechanical power is now too well known in a general way to warrant taking up time and space with historic data as to discovery or application, but it remained for the present generation to develop its application to the many methods that have proved invaluable n engineering and mechanics, among which are the several uses to which it may be applied in water works construction.

It may be generally assumed that the "*original work*" in connection with this most necessary branch of the public service is performed in the civic or water company's board room where "air" is usually so "free" that compression is not a necessary factor, sufficient exhaust being provided the scheme of the water works system in due time reaches the pipe foundry where omitting the "blast" necessary for the cupola we find modern plants using "air" machines in moulding the pipe, drying the moulds by "air" blasts, and after removal from that section of the foundry another "air" machine removing the hard burned core from the interior of the pipe after cooling by a single stroke of the piston, and as the pipe continues its way along the "*skids*" an air hammer with proper tools removes any excess material or irregularities in manufacture, properly clearing the hubs, etc., a visit to the foundry clearly demonstrating the efficiency of the "air" method in the production of pipe of uniform quality, and as a labor saver.

Leaving the foundry, a short trip through any of the large "steel" works quickly brings to "*hearing*" and notice the presence of the "air" machines where the work of producing "steel" conduits and the other accessories of a water works system in which this material is frequently used has been completely changed since the general introduction of compressed air to replace hand work in manufacture, and the result is quite apparent in the more uniform quality and finish of the work obtained.

With the material so produced and delivered, comes the process of construction proper as generally relating to the underground

portion of the system, which in many towns and cities implies the simple excavation of "Good" earthy material and the item of pipe laying detail.

In many other cities, however, "rock" is a factor to be dealt with in excavation that in by-gone days was a tedious job for the hammer and hand drill, supplanted later by the steam driven outfit, generally expensive, cumbersome and ill adapted to work in northern climates during cold weather.

Compressed air as a power for this class of work may be, and in the case of large works often is, developed in Central stations entailing construction of extensive (air) pipe lines, costly to construct and operate owing to "air" loss, leaks, etc., but in such cases unavoidable; the motive power for the compression plant being readily adapted to steam, gas, gasoline or electric, as the local conditions warrant.

For ordinary construction in rock or partly rock trenching, however, there are now several types or makes of gasoline-driven air compressors, erected as a complete unit on trucks that furnish a most satisfactory outfit for contractors or water works department use, having power to operate two or more small drills, such units being economical in initial and operative costs, and with proper tools and handling giving excellent results compared with larger central stations, having the additional value of (by being portable) being used on works where the installation of the larger stationary plant would be prohibitive.

Such a portable unit has been used advantageously as a power hoist by attaching a drum to the truck frame, and the pipe laid in position for pouring there with, when the "air" is again used for caulking with marked efficiency in quality of work done and economy as compared with hand work, more particularly in pipe lines 20 inches and upwards, experience demonstrating that one good caulker using an air hammer will do the work of four or more working with hand tools, and the finished work will be much more uniform and of better character.

In case of wet trenches such a unit can be easily rigged to operate the pumping either by air, or by using the power end to operate any type of portable pump.

Following the completion and satisfactory testing of a section of pipe line the backfilling becomes a feature where the "air" may once more be used in connection with a compressd air tamping machine, where on paved or other streets it is essential to thoroughly

compact the backfilling, such machines being said to give satisfactory results both as to work and costs compared with manual labor.

When not in use on the outside construction the compressor unit becomes a valuable adjunct to the equipment of the work shop where there is frequently work of a character that is difficult to perform with a fixed machine tool, that can be readily done by the "air" tools, and many odd jobs of cutting, drilling, chipping, riveting, etc., done quicker and better thereby and frequent worry avoided when such "little things" can be hurried in an emergency occasion.

While the piping system is in most instances a matter of material and mechanical detail there are a number of the larger cities, more particularly those located along the lakes where the "intake" has become the principal feature of the system, notable among these being Chicago, Cleveland, Buffalo and Toronto, where owing to conditions affecting the supply it has been necessary to resort to tunnels for long distances below navigable water where the character of the material through and under which these tunnels were driven rendered the use of compressed air an absolute necessity, where the pressure chamber has to be used for the exclusion of water, etc., and under such conditions the air driven tools are indispensable.

The general methods of working application of "air" and other details involved in this class of tunneling where the work has to be performed under pressure have been so frequently described in the engineering press in connection with the above named works and others of similar nature that it would be imprudent to elaborate thereon, as while presenting in a general way the adaptation of compressed air it was not intended to delve into any detail that might prove misleading, in application to similar works where the general conditions require to be carefully studied and worked out to meet the local conditions developed.

DISCUSSION

Mr. Milne: When the question of the use of compressed air was brought to my notice for caulking, we had in contemplation what to us was quite a large job on the smaller section of a 30-inch main involving rock cutting 4200 feet at an average depth of 14.2 feet, some of it through very hard rock. The installing of a permanent plant would have been prohibitive on the basis of the estimates submitted. Look-

ing over the field for some way of reducing the cost I consulted with Superintendent Callahan and he told me that he had been using in their construction a portable unit for such purposes. As a result I purchased a second-hand 6 x 8 air compressor, got hold of an old 80 gallon hot water tank, tested it and found it did not leak, and used it for my storage system. Fitted up a 30-gallon tank that I bought from a plumber for my cooler, and mounted the whole apparatus on a pair of trucks, and tried it out. An Ingersoll hammer was about the only thing new in the outfit. My caulker who can crawl through an ordinary 8 or 10-inch hole can get in under a hub or bell, and my cost on the air work has been only 25 per cent of what it would have cost me for manual labor.

A MEMBER: I would like to ask if you used compressed air for pipe cutting?

MR. MILNE: We use the air to advantage in cutting large pipe by using a diamond point in circling to define the cutting line, which however could be done better and just as quickly with a sledge and chisel, as the vibratory result of the rapidly moving hammer might deflect the cutting line to the detriment of the pipe cutting.

STERILIZATION OF WATER BY ULTRA VIOLET RAYS

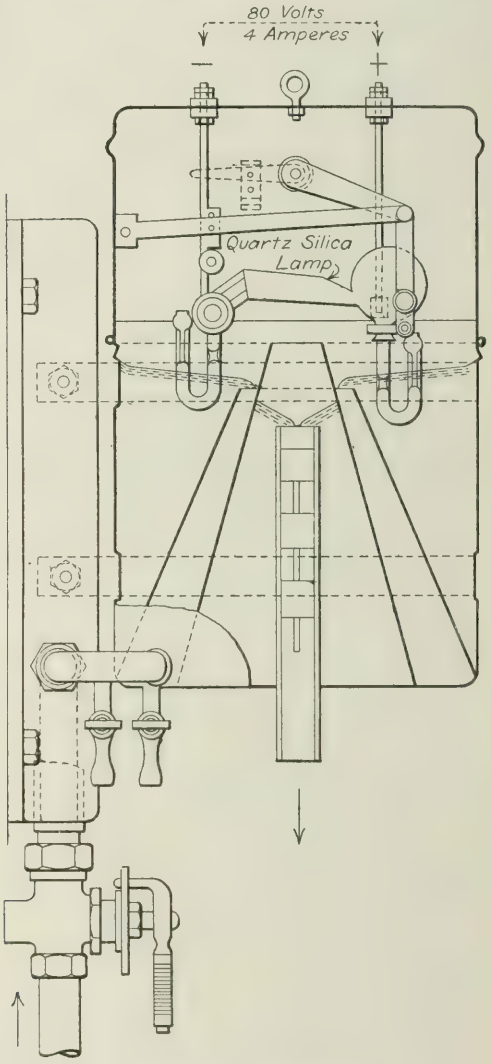
By A. E. Walden and S. T. Powell

With the constant and ever increasing demand for pure water, there has naturally been an increase in the number of purification methods. The main object of all these processes has been the elimination of pollution, especially disease producing bacteria, but popular demand has also required that the color and suspended matter that is in the water shall also be removed. Sand filtration, either by the English or rapid method, has up to the present time proven the most satisfactory means of accomplishing these results, but sand filtration at its best is expensive treatment; and any auxiliary method that may be used in connection with it and at the same time produce the desired results, at a lower cost, will undoubtably be of interest to those who have to deal with this phase of sanitary science. It is for this reason that prefiltration in connection with slow sand filtration, and the sterilization of the effluent from filters, by hypochlorite of lime, has been so earnestly investigated during the last few years.

The use of ultra violet rays for water purification is a sterilizing process in which the rays simply destroy the bacterial life in the water, with no appreciable chemical or physical changes. Although the process is efficient for the sterilization of water supplies containing a moderate amount of turbidity, its greatest use is as an auxiliary method for the complete removal of bacterial life, after the water has passed through filters. The reason for this is that the rays are absorbed by opaque bodies, so that to obtain the greatest efficiency from the apparatus, it is necessary to remove all matter in suspension in the water.

Ultra violet rays were first produced on a large scale by Professor Finsen, using an electric arc between metallic electrodes, or the discharge from a condenser through a series of points. Professor Finsen used the rays only for therapeutic purposes, in the treatment of such maladies as cancer. The system, though, was not developed to be of commercial advantage, and it was not until the perfection

of the mercury vapor lamp, using a silica tube, that sterilization of water by these means became a possibility. By the use of this lamp, it became possible to generate an arc rich in ultra violet



Domestic Sterilizer

rays, which readily passed through the silica tube. Silica tubes are used as the rays are almost completely absorbed by glass.

A domestic sterilizer using this type of lamp (diagram 1) was

BACTERIA PER CUBIC CENTIMETERS							B. COLI				TURBIDITY		COLOR		VOLTS	AMPERES
RAW	STERILIZED					AVERAGE EFFICIENCY	RAW		STERILIZED		Raw	Sterilized	Raw	Sterilized		
	1	2	3	4	AVG.		Tests Made	Tests Positive	Tests Made	Tests Positive						
450	2	0	0	2	1.0	99 78	4	0	16	0	20	20	22	22	80	4
580	7	4	6		5.6	99 04	4	1	16	0	14	14	16	16	80	4
1390	5	2	0	4	2.7	99 81	4	2	16	0	15	15	14	14	80	4
310	8	4	2	0	3 5	98 78	4	3	16	0	12	12	10	10	80	4
490	4	6	6	2	4.5	99 09	4	2	16	0	18	18	12	12	80	4
210	0	0	4	2	1.5	99 29	4	0	16	0	20	20	12	12	80	4
600	0	0	0	1	0 2	99 97	4	1	16	0	16	16	10	10	80	4
720	4	2	0	3	2 7	99 63	4	2	16	0	15	15	8	8	80	4

imported recently, by the Baltimore County Water and Electric Company, for experimental purposes, and was installed at the company's office at Baltimore, Md. The water used for the test was city water just as received from the tap. This water often contains B. coli, and the number of bacteria per cubic centimeter is usually in the hundreds. The table given here shows the results of the tests made, and it is readily seen that the effluent in all the tests that were made was practically sterile.

The destruction of bacteria by the rays is almost instantaneous, as it requires but a few seconds for the water to pass through the sterilizing chambers, while the organisms are subjected to the rays even much less time, as the rays penetrate the water but for a few millimeters. The lamp is said to produce an arc that is richest in ultra violet rays when it has obtained a temperature of about 800° centigrade, but under the conditions that this test was made, this could not be determined. The lamp generates considerable heat, as is seen by the diagram shown here, which gives the rise in temperature of the case of the sterilizing chamber directly above the lamp. The destruction of bacterial life in the water is not due to the heat generated by the lamp, as the water passes through the chamber so rapidly that there is no rise in temperature of the water.

The bacterial results from these few experiments are quite the same as the more extended tests carried on last July at Marseilles, France. The capacity of the apparatus in the French test was 158,500 gallons per twenty-four hours, and the process required 98.41 watt hours per 1000 gallons. The apparatus was attached to the outlet of a roughing filter, which was used simply to remove the turbidity from the river water. The water before being subjected to the rays from the mercury vapor lamp, contained several hundred bacteria per cubic centimeter, and positive results were obtained for B. coli. in all 1 cc. samples tested. All of the samples from the effluent were practically sterile and B. coli was entirely eliminated as well as pathogenic organisms with which the raw water had been inoculated.

The use of ultra violet rays for water purification has much to recommend it, and although the use is yet too limited to form any idea as to its adaptability on all supplies, on account of the high cost of the lamps, still its efficiency as a sterilizing agent cannot be questioned. The present cost of the lamps will undoubtedly have to be reduced, and some method of operating the lamps in series will have to be devised before the system can compete with many of

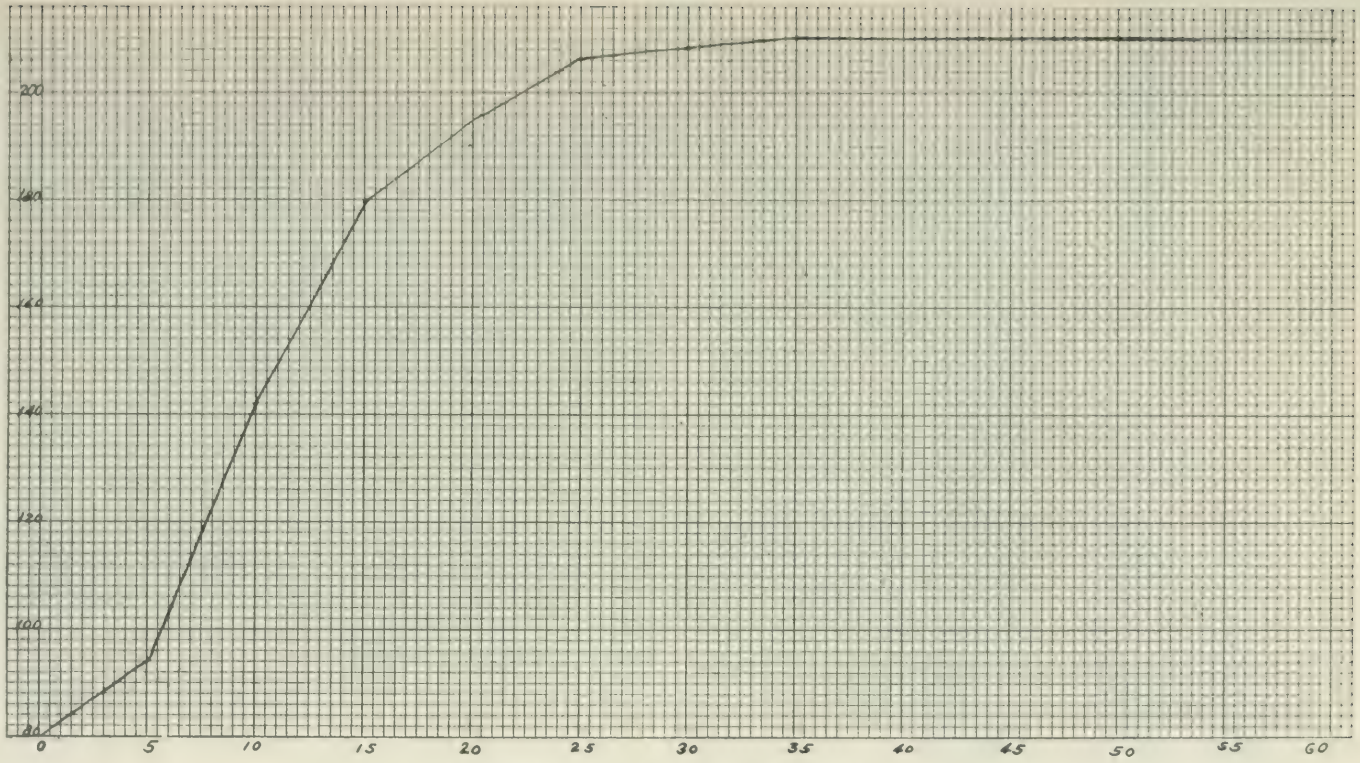


TABLE SHOWING RESULTS OF TESTS MADE

the successful methods of water purification that are in use in this country at the present time.

The rapidity of the action in destroying bacterial life, the compactness of the apparatus, and the comparative simplicity of the operation, are features that will appeal to many engineers where these things are of prime importance.

DISCUSSION

MR. DIVEN: The paper gives no data as to cost, that is information that we would like to have.

WATER SOFTENING BY MEANS OF ZEOLITH

By Boris N. Simin

Until recently, the only rational method of water softening in use, has been the well-known Clark's lime-and-soda method except for the use in special cases of barium hydroxide. For the application of Clark's method, many different forms of apparatus have been constructed, consisting essentially of dosing appliances, reagent and precipitation tanks.

Recently, however, Professor Robert Gans, of the Royal Geological Academy at Berlin, devised an entirely new and elegant method of water softening, having great practical advantages.

A purely scientific study of the group of natural minerals, called zeolith (aluminate-silicates), led Professor Gans to this important practical discovery.[1]

These minerals exist in almost every soil, in a finely divided form, and their tendency to enter into chemical exchange reactions gives them great importance in nature's economy and in agriculture.

The successful artificial fertilization of soil, by the application of ammonium, potassium and phosphate salts, greatly depends on the presence of zeoliths, which bind and retain, during the long period

[1] Dr. R. Gans, Zeolithe und ähnliche Verbindungen, ihre Konstitution usw. *Jahrbuch der Königlichen Geologischen Landesanstalt und Bergakademie*. Berlin, 1905, S. 179.

Dr. R. Gans, Konstitution der Zeolithe, ihre Herstellung und technische Verwendung. *Ebenda*, 1906. S. 63–94.

Dr. R. Gans. Reinigung der Zuckersafte von Kali usw. *Zeitschrift d. Deutschen Zuckerindustrie*. 1907. Bd. 57. Seite 206.

Dr. R. Gans. Verbesserung von Trinkwasser u. Gebrauchswasser für häusliche u. gewerbliche Zwecke durch Alluminat-Silicate oder künstliche Zeolithe. *Mitteilungen aus der Königlichen Prüfungsanstalt für Wasserversorgung u. Abwasserreinigung*. Berlin, 1907, Heft 8.

Dr. R. Gans. Reinigung des Trinkwassers von Mangan durch Aluminatsilicate (*Chemiker Zeitung*, 1907, N. 28.

Dr. R. Gans. Ueber die technische Bedeutung der Permutite (der künstlichen Zeolithartigen Vervindungen. *Die Chem. Industrie*, XXXII. N. 8, 190.

Dr. R. Gans. Die Mangan-Gefahr bei der Benutzung von Grundwasser zur Trinkwasserversorgung und deren Beseitigung. Berlin, 1910.

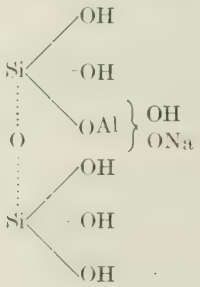
of vegetation, the fertilizing elements which otherwise would be washed out by the first rain and which thus could not be sufficiently used by plants.

Following nature's processes, Professor Gans proposed to use the permutative capacity of the Zeolith for water softening: to remove the calcium and magnesium from hard water, by filtering the water through zeolith.

Studying the various natural zeoliths, Professor Gans observed that all of them have a rather low permutative capacity, and he therefore directed his attention to the artificial preparation of zeoliths in his laboratory, obtaining very interesting results. By melting together kaolin, quartz and soda, at high temperature, under conditions similar to those usual in glass furnaces, he obtained the soda aluminate-silicate in the form of a zeolith sand, called "permutite." The chemical composition of this substance is:

	Per cent
Silicon oxide, SiO_2	42.80
Aluminum oxide, Al_2O_3	23.12
Sodium oxide, NaO_2	14.50
Water, H_2O	20.17

For this sodium zeolith, Professor Gans gives the following structural formula:



The permutative capacity of this artificial zeolith is much higher than that of any known natural minerals of that group, being practically about 2 per cent; in other words, 100 kilograms of zeolith sand are sufficient to remove, from the water, about two kilograms of calcium oxide, (or its equivalent amount of magnesium oxide).

The fact is that simple filtration of a hard water, through a layer of coarse zeolith sand about one meter thick, at a rate of 1 to 4 meters per hour, depending upon the degree of hardness suffices to render the water absolutely soft; the calcium and magnesium ions being replaced by an equivalent amount of sodium from the zeolith.

Evidently, the sodium zeolith, in this process, loses its sodium (which is replaced by calcium and magnesium from the water), and is thus transformed into a calcium and magnesium-zeolith. Therefore the practical value of this method depends on the possibility of an easy regeneration of the zeolith, i.e., of its easy re-conversion from a calcium and magnesium zeolith into a sodium zeolith. Be it understood that there is no precipitation of calcium and magnesium carbonate, which certainly would clog the zeolith filter. The calcium and magnesium ions, removed from the water, take the place of the sodium in the zeolith, the appearance of which is not changed by this process.

The regeneration, which restores the sodium to the exhausted zeolith, is accomplished by means of a solution of common salt (sodium chloride). Under the influence of the higher concentration of sodium ions, the inverse exchange reaction takes place according to the phase law: calcium and magnesium ions, which have been retained in the water by the zeolith, now give place to the sodium ions from the salt solution, and the residue of the salt solution (which has to be washed out after the regeneration has been finished), carries away with it the calcium and magnesium in the form of dissolved chlorides.

This is an exceptionally elegant example of reversed chemical reaction, and one which, according to Doctor Dorochewsky and his assistant Doctor Bardt, of the Moscow Central Laboratory of the Ministry of Finance, is extremely valuable for theoretical research in connection with the phase law of the celebrated American chemist Gibbs.

The zeolith method of water softening entirely obviates the dosing with reagents and the formation of precipitates. A simple filtration, through the zeolith sand, perfectly softens every water, independently of the variations in its hardness. The periodical regeneration, during the rest hours, every night or every week (according to the amount of zeolith sand placed in the filter), is also accomplished simply by passing, through the filter, a sodium chloride solution of a concentration of 5 to 10 per cent. This process of regeneration requires from four to eight hours.

The only operating expense, for water softening, consists in the supply of common salt for regeneration, the amount of which is about eight times the weight of calcium oxide equivalent, removed from the water by the zeolith.

A small zeolith water-softening plant (Fig. 1) has been working, for about a year, with a 110 h.p. boiler at a flour mill at Kirsanoff, Russia.

It consists of two cylindrical iron filter tanks of three feet diameter, working alternately during 12 hours at a rate of 1.5 meter per hour. The filters contain zeolith sand sufficient for the complete softening of 6000 U. S. gallons (22,700 liters) per twenty-four hours, the hard water containing 0.40 gramme calcium oxide and 0.06 gramme mag-

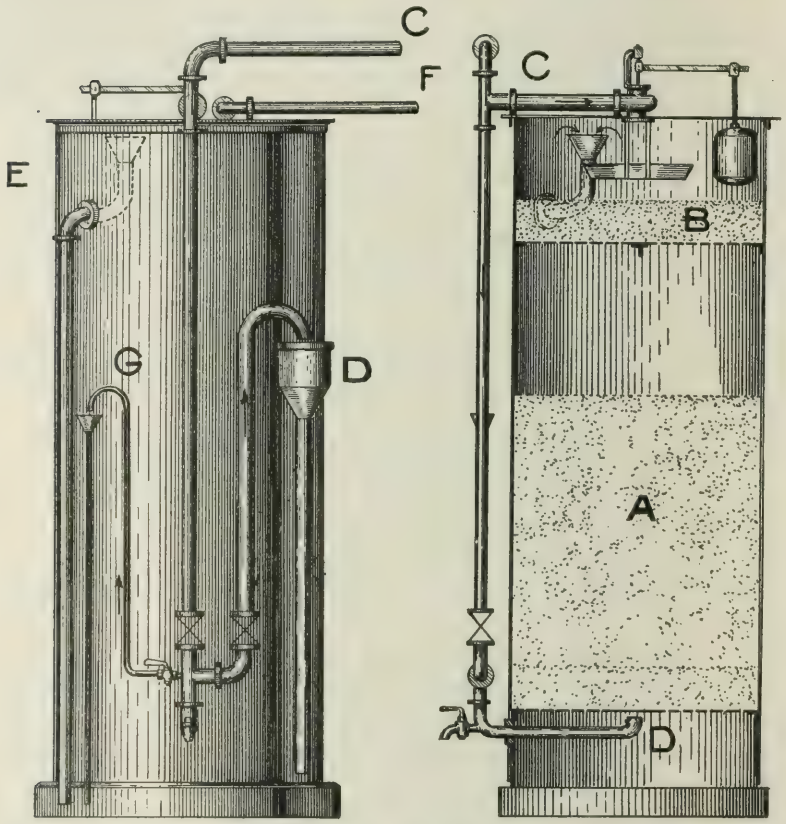


FIG. 1. ZEOLITH WATER SOFTENING PLANT

nesium oxide, per liter, making 48 German degrees of harness. This is equivalent to $40 + 6 \times 1.4 \times 2 = 56.8$ parts of CaO per 100,000 parts of water—and the complete softening of the 6000 U. S. gallons of such water consists in the removal of $\frac{22{,}700 \times 56.8}{100{,}000} = 12.9$ kilograms of calcium oxide equivalent, which otherwise would be daily deposited in the boiler, in the form of scale consisting of calcium and magnesium carbonate and sulphate.

Each of these filters, working alternately, has to be regenerated by sodium chloride solution after twelve hours work. The amount of salt, used for the daily regeneration of the two filters, is 12.9 x 8 = 103.2 kilograms of dry sodium chloride.

Thus, for the softening of 6000 U. S. gallons of water, of 48 German

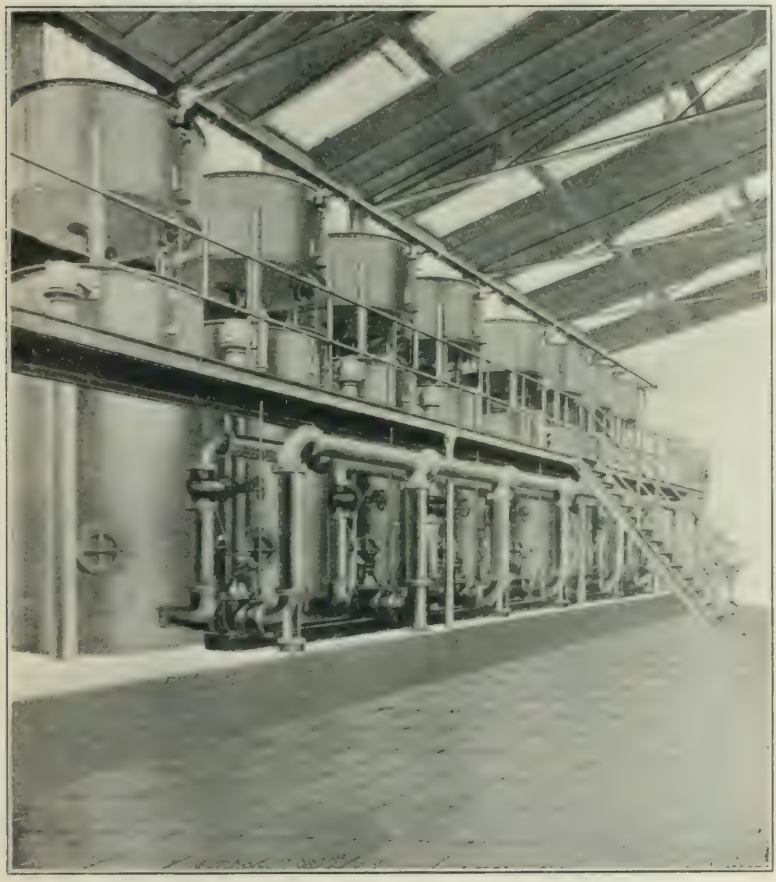


FIG. 2. PLANT IN A BREMEN TEXTILE MILL

degrees of hardness, 103.2 kilograms of common salt are used, or 1.7 kilograms of salt per 100 U. S. gallons of water. The softening is complete to 0 degree, and only before the regeneration the hardness of the filtrate increases to about 3 German degrees.

The sole chemical change, in water softened by the zeolith method, is the replacement of calcium and magnesium ions by an equivalent

amount of soda ions, all the scale-forming elements being replaced by easily soluble sodium salts.

The perfect results, obtained by Professor Gans's new method, leave no doubt of the displacement of the old Clark method of water softening by dosing with lime and soda reagents, especially in cases where the permanent hardness is high and where the use of the expensive soda carbonate reagent can be profitably replaced by that of cheap common salt, to be applied to the zeolith.

The first cost of installation depends principally upon the cost of the artificial zeolith. The installation of the above mentioned small plant, for 6000 U. S. gallons per day of extremely hard water (48 German degrees), sufficient for the feed of a 110 h.p. boiler, costs less than $1000, including the interests of the patent-owners in Germany.

The three years of work, of the first permutit water softeners installed in Germany, showed that not more than 5 per cent of the zeolith has to be renewed yearly. The exchange capacity of the zeolith does not diminish even after hundreds of regenerations.

There are already more than 250 zeolith water softening installations, of different sizes, in Western Europe, mostly in Germany. The largest of these, at a textile mill in Bremen (Fig. 2) handles 300 cubic meters per hour. About fifteen zeolith water softeners are already at work in Russia.

It seems inevitable that Professor Gans's new and epoch-making method of water softening, must, in a few years, find extensive application in the United States, not only for boiler-feed water, laundries, bath-houses, etc., but also in water-supply practice.

SOME WATER WORKS EXPERIENCES IN INDIA

By R. W. Lawton

To the American water works engineer living in the Orient for nearly a decade as the writer has, the *Proceedings of the American Water Works Association* are always doubly interesting inasmuch as the papers are instructive and are often written by old friends, the mention of whose names often bring back reminiscences of other days when some of us were in "God's country." The writer often wonders if the members of this Association realize the problems of water works construction and management in a country like India. At the risk of being accused of "drawing the long bow," the writer will relate very briefly a few of his experiences and conclude by describing a novel elevated storage reservoir recently constructed for the city of Calcutta.

Outside of a few cities like Calcutta, Bombay, Madras and possibly one or two others, water works in this country are usually constructed and controlled by government and in all cases they are kept up by indirect tax. In many cases practically no house connections exist as the water is usually taken from street hydrants and carried into houses in goat skins called "Mussuks." In cases where house connections do exist such connections represent a very small proportion of the total number of people supplied.

Here superstition and caste prejudices play a large part in the supply of good water. For instance, it is impossible to use leather in foot valves or any other part of pumps or water apparatus, as the use of the same would pollute the water for a large number of people. Also it is impossible to use tallow or grease containing any animal fat about a water works as this also is considered of a polluting nature. The writer has even known cases where native chiefs and officials have requested that certain men be discharged from employment in water works because these men were low caste and as such by their very presence in the works would pollute the supply.

The horoscope, especially in native states, plays a very important part in the starting of a new works into operation, and the writer has waited almost a week after having notified the officials that a

plant was ready for operation, because the astrologer called in to set the starting date, named the auspicious hour a week ahead. In matters of this kind it is useless and very undiplomatic to endeavor to change the order of things and he who would succeed in the East will not endeavor to hustle or reform the people.

Caste principles and religious prejudices which will frequently prevent the people from using a good water supply, promises immunity from danger when they go to the other extreme and use water unfit for human consumption. The writer has seen natives drawing water from a ground tank in times of cholera epidemic where a corpse was floating on the surface, which water they were using for domestic purposes, and in which they also bathed and washed their clothing.

On one occasion when employed in disinfecting tanks in a district where cholera claimed 5000 victims out of a population of 20,000 within six weeks, the writer was under armed protection while applying the chemical, for it was generally believed that he was poisoning the water and but for the protection referred to he would have suffered bodily harm if not the loss of his life. On a neighbouring hill side a little band of native coolies with drums and other instruments of like nature, by means of a horrible din, were trying to appease the spirits who had brought the epidemic among them.

Almost the entire supply on which the districts above referred to were dependent was mine water pumped from the pits and containing large numbers of cholera bacteria. On this occasion the writer has seen hundreds of bodies (or rather bones and bodies) lying out in the open, for no serious attempt was made to burn or bury them owing to the small number of Europeans present and general demoralization. The vultures and jackals make quick work of the bodies at such times, however.

Prejudice is often so strong against the use of pumped water that the writer has known cases where such water was not used for a considerable time after the water works had been put into operation. Before the water was generally used by the people, it was necessary for the European officers to walk about the town daily, drinking the water from taps in public places that the population might see that no harm came to them therefrom. In many cases the priests of the village or town have been the cause of the non-use of water by the people.

CALCUTTA WATER WORKS

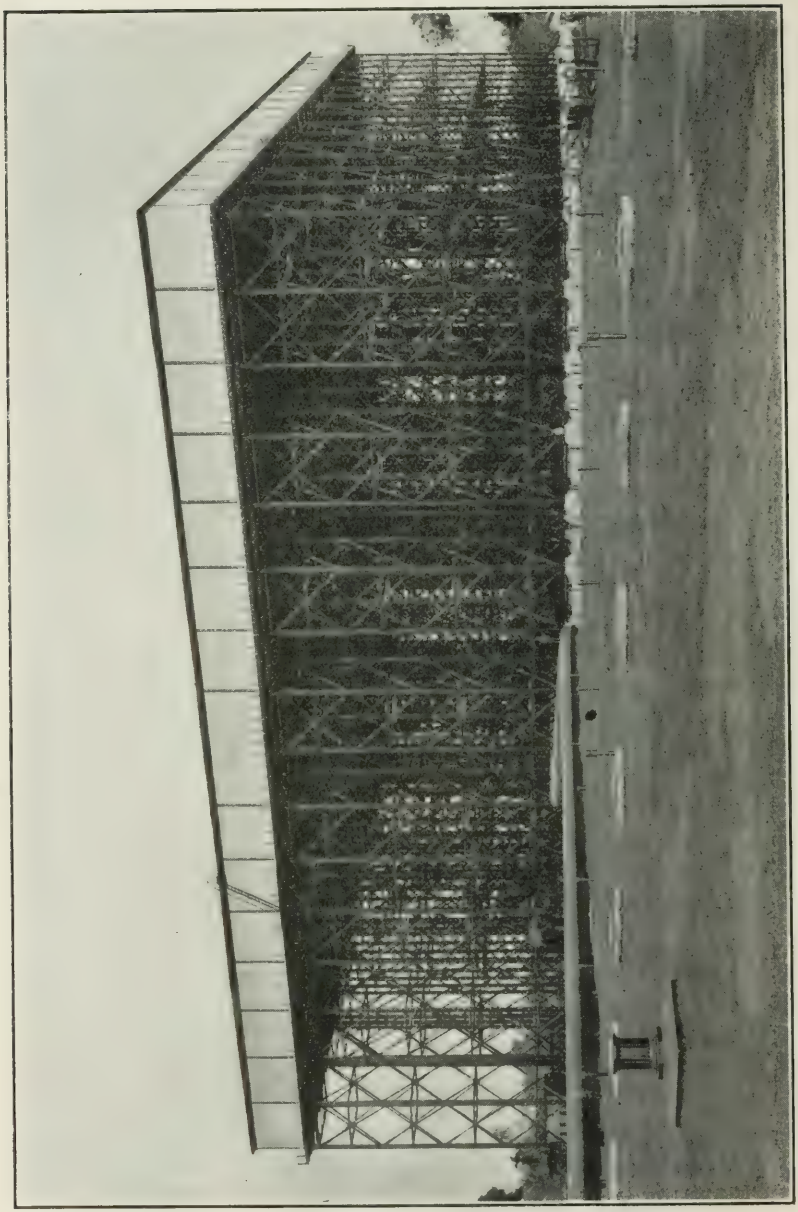
Calcutta being located on the river Hooghly and the capital city of India, enjoys conditions with regard to water works operation which are found in practically no other city in India. Here there are about 35,000 house connections with a consumption of 40,000,000 gallons daily. The total taxation amounts to 19.5 per cent of the appraised valuation of property (which represents approximately the rent value), 6 per cent of which is applied to maintenance of water works. For every one rupee ($0.32) paid in taxes each rate-payer is entitled to 5000 gallons daily, and meter rates for water sold by measurement is Re. 1/- per each 3000 gallons consumed.

There are two supplies in this city, one being for filtered water, the other for watering the streets and flushing purposes. The filtered water supply is taken from the Hooghly River at Pulta some twelve and one-half miles from this city. At Pulta the water is settled in large settling tanks after which it is filtered through sand bed filters having a total area of twenty-one acres. An excellent description of these water works was given in a paper read by Mr. George A. Johnson before the Society in 1907 (see pages 270, 271 and 272 of the 1907 *Proceedings*).

Since Mr. Johnson's paper was written a raised reservoir of 9,000,000 gallons capacity has been erected in connection with the Calcutta Water Works, and as this tank is probably the largest of its kind in the world, a detailed description of the same may prove interesting.

Before proceeding to describe the raised reservoir and its construction it would be well to explain the reason of its existence and the functions which it will be called upon to exert. Under the existing conditions, after the water is filtered twelve and one-half miles from this city, it is pumped down to Tallah, a receiving station on the outskirts of this city through two cast-iron mains of 48-inch and 42-inch diameter, respectively. It is received at Tallah in underground reservoirs having a capacity of 8,000,000 gallons. From these reservoirs the pumping engines at Tallah pump the water through two 30-inch mains to three other receiving stations, from where it is served to the consumers by means of three separate pumping stations. This completes the distribution by maintaining a pressure directly in the main, during certain hours of the day only.

If the demand for water remained constant throughout the twenty-four hours, the work of distribution would be a simple one, but the



THE TANK OR RESERVOIR

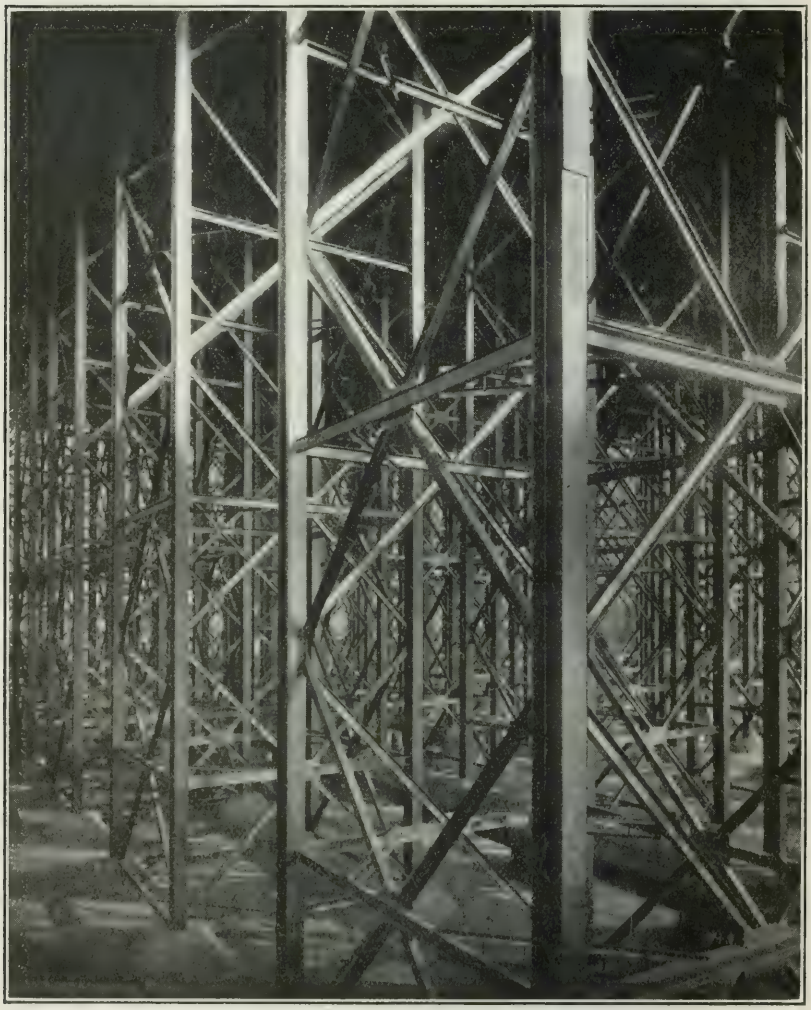
demand varies greatly so that it is impossible to maintain an even pressure on account of there being no balance tank. The consequence has been that the pressure has been lowered to practically nothing in the mains when it was most needed, *i. e.*, at the period of maximum demand, and raised above what was required at the period of minimum demand. Under the circumstances it was necessary to devise some method of meeting the conditions. In localities more favored by nature the balance is usually provided for in a reservoir upon some convenient eminence, as is well known, into which water is pumped and from which it gravitates to the districts to be supplied but in Calcutta there is not a hill within one hundred miles, and it was to provide for this local defect in nature that the construction of a raised reservoir became necessary. The functions of this reservoir are, therefore, to provide an automatic balance and to regulate the inequalities between supply and demand and to maintain a sufficient head of water throughout the city at all hours of day and night.

FOUNDATION

The first consideration in the construction of a large tank to hold 9,000,000 gallons of water is naturally the nature and sufficiency of the foundations. In the Tallah reservoir the 9,000,000 gallons of water account for some 40,000 tons, while the structure will account for another 8500 tons, and it was decided to spread this weight over an area of 342 x 342 feet or (say) 117,000 square feet, or say 12 hundredweight per square foot, including the ferro-concrete foundation.

The site selected for the reservoir was a piece of land near the pumping station, the soil consisting of the usual fine sand and clay as met with throughout Calcutta and the neighborhood. The area was interspersed with the usual ground tanks excavated to a depth of 13 feet or thereabouts. It was evidently useless to excavate for a foundation, and it was decided to construct one on the surface of the ground. The tanks were first dewatered, all mud and soft earth removed, and the area of the tanks piled with piles 20 to 25 feet long, after which the tank was filled with broken brick carefully rammed and consolidated in layers up to the ground level. The whole area of the reservoir was then rolled by means of steam rollers, all soft spots investigated and made good by means of piles and broken brick filling, and when, under the application of a 15-ton roller, a firm bed had been obtained, a bed of broken brick 9 inches in thickness was laid down and rolled by means of steam rollers of increasing

weight until a firm, level road-like bed was obtained. In order to prevent the "spreading" of the subsoil a protective wall formed of two rows of close piles 25 to 30 feet long and 3-foot centers, the space



Steel Structure for the Support of the Reservoir

between the piles being filled in with lime concrete, was constructed at all points which from their surroundings appeared to require such protection.

Upon the bed of broken brick the foundation proper was constructed, consisting of 2 feet 6 inches of cement concrete reinforced by flat steel ties 6 x ½-inch near the base of the concrete and 6 x 3-inch rolled steel joists near the surface. These ties and joists are laid east and west and north and south, the joists superposed over the ties. The ties and joists laid east and west are spaced 3 foot 4-inch centers, while those laid north and south are grouped together in sevens under the column bases at 1-foot centers.

STRUCTURE

The steel structure for the support of the reservoir consists of 17 x 12-inch broad flanged beams as columns braced together in fours to form trestles 20 feet square. These trestles are single throughout the structure, excepting at the south and east sides where two trestles are braced together to give additional stability against wind pressure, etc. The columns rest directly on the upper or north and south rows of 6 x 3-inch foundation joists previously referred to, the weight being spread over the joists in the usual manner by means of riveted steel bases which are now filled in with concrete for the protection of the steel work from corrosion, and for additional strength and stiffness. The columns are $88\frac{1}{2}$ feet high and weigh $4\frac{1}{2}$ tons each. There are 289 columns in the structure and each will carry a weight of about 200 tons.

On the top of the columns two 24 x 12 inch x 158-pound broad flanged beams are laid side by side running north and south at 20-foot centers, and upon these main girders, secondary girders 15 x 6 inches x 59 pounds are laid east and west at 2 foot $2\frac{2}{3}$ inch centers.

THE TANK OR RESERVOIR

Upon the 15 x 6-inch secondary girders referred to in preceding paragraph, a bed for the tank plates has been prepared by the provision of teak packing pieces 6 x 4-inch section dipped in hot tar, laid the whole length of the secondary girders, and upon this bed the tank bottom rests.

The tank or reservoir is 321 feet square and 16 feet deep, and is divided into four compartments of equal size. The compartments serve the double purpose of minimizing any possible danger to the reservoir in the event of an earthquake by reducing the wave length of the water in the tank, and they further facilitate the working in

that one or more sections of the tank can be emptied for examination, repair or painting, while the remaining sections are in use.

The tank bottom plates are 4 feet wide lap jointed and are $\frac{3}{8}$ inch thick, rivetted together with $\frac{3}{4}$ rivets 2-inch pitch. The floor angles are 5 x $3\frac{1}{2}$ x $\frac{3}{8}$, and to these the side plates 4 feet wide are stayed at intervals of 2 feet by means of a $\frac{1}{4}$-inch gusset plate at the base and three raking flat ties 3 x $\frac{3}{8}$, 3 x $\frac{3}{8}$ and 2 x $\frac{5}{16}$.

These ties are joined to the tank bottom by means of angles 5 foot x $3\frac{1}{2}$ x $\frac{3}{8}$ inch, and to the tank sides by means of an angle 5 foot x $3\frac{1}{2}$ x $\frac{3}{8}$ inch running from the top to the bottom of the tank. In addition there are channels 4 inch x 3 inch x $\frac{3}{8}$ inch fixed in place of the 3 x $\frac{3}{8}$-inch flat ties at intervals of 10 feet all round the tank. The partitions are constructed and supported in a manner similar to the tank sides but without the channel stays referred to in the previous paragraph.

THE ROOF

The roof is supported by means of columns superposed on the main columns of the structure. These columns support 12 x 5 joists laid north and south, which in turn support 8 x 4 joists laid east and west at 6 foot, 8-inch centers, and upon these are laid the 2 x 2 x $\frac{1}{4}$ tees spaced to carry tiles 12 inches wide.

Recently the reservoir has been filled and found to be perfectly tight, and the average settlement of the entire structure was 6-inch which was comparatively evenly distributed and only on one side was there a slight variation, this being the portion over a former ground tank which had been piled and in the settlement these piles did not settle quite evenly with the rest of the foundation.

PHOTOGRAPHS

Attached will be found two photographs which will give a much better idea of the reservoir as it appears completed.

The writer is indebted to Mr. W. B. MacCabe, M.I.C.E., Chief Engineer of the Calcutta Municipality, and to Mr. Arthur Pierce, A.M.I.C.E., Assistant Engineer of the Water Works, for much of the detailed information given above.

THE INVESTIGATION OF UNDERGROUND WATER WASTE IN WASHINGTON, D. C.

By W. A. McFarland

The matter of detecting and closing underground leaks in the distribution system is one that the water department of Washington has been working on systematically and rather extensively since 1906.

At that time the rapid increase in both mean consumption and per capita rates made it quite evident that unless radical measures were taken the city would soon be face to face with at least a partial water famine; the increasing danger had been recognized for years, but shortage of funds and the failure of Congress to authorize the general installation of meters had prevented taking up the work on an effective scale.

The per capita rate, based on the entire population, was 169 in 1896 and 217 in 1906, while the mean daily rates for the two years were 44,500,000 and 67,500,000, respectively.

During a short period of unusual cold in the winter of 1904–5 the consumption exceeded the capacity of the conduit supplying the city, and the local reservoirs were drawn down close to the danger line. Before the trouble reached the consumer the weather moderated, and conditions again became normal.

Among several means used to decrease the great waste of water was the systematic search for and repair of such underground leaks as showed no evidence on the surface.

The division in charge of this work was organized in September, 1906, with a party of about six men, which force has been increased until at the present time it consists of about thirty men, with five horses and wagons. This force is divided into four field parties with necessary clerical and drafting force to properly record the work as it progresses, and is employed exclusively in the search for leaks which, when found, are at once repaired by others.

The principal instruments used in the work are the pitometer, and the aquaphone; the former, as is well known, being a device by means of which the velocity of flow at any point in a main may be determined readily and without undue expense, and the latter an instrument

resembling a telephone receiver, by means of which the sound of water escaping under pressure from a leak, flowing through a service pipe or through a partially opened valve may be detected.

During the early periods of the work the usual method of procedure was to isolate a comparatively small part of the distribution system so that the entire supply was drawn through a single main—usually 6 or 8 inch—place a recording pitometer on this supply line, and take continuous records, usually for several days, of the rate of flow into the district. If this record showed an abnormal night flow—which it generally did—the isolated district was further subdivided by cutting off the flow from the individual premises in a single square and subsequently from the square itself, noting the time of each cut-off, and subsequently studying the several drops in rate indicated on the photographic chart from the recording pitometer. This, obviously, would give the rate of flow into each service pipe inside of the curb stop, and also the amount unaccounted for in the house services, and presumably due to main leakage, or to leakage in the service pipes outside of the curb stop.

Much good work was done by this method, but serious difficulties developed. The isolating of a district for several days at a time during which its entire water supply was drawn through a small service main was a serious menace in case of fire; means were taken to insure the prompt opening of other valves in an emergency, and no ill effects ever resulted, but there was no doubt a distinct element of hazard.

The use of the photographic record necessitated delay in analysis when accurate results and corrective measures—especially in the case of wilful waste—were dependent on prompt action.

Then, too, the photographic record was sometimes defective; whether this were due to defective mechanism, unskillful handling or accident, the result was the same—the whole thing to do over again.

Our present method was planned with a view to overcome these objections as far as possible and is briefly as follows.

The entire distribution system is divided into a number of comparatively large districts, each having an area of about 1100 acres, and with population varying from 13,000 to 30,000. Each of these districts can be so isolated as to draw its water supply through one of the larger trunk mains, thus eliminating the fire risk.

On the trunk main entering the district is located a permanent connection for a recording pitometer, and, if the main passes on through, a second connection is placed at the point of egress.

At intervals, continuous seven-day records are made for each of these districts and carefully filed for reference, thus giving us a means of making accurate comparisons from year to year as the work progresses.

Permanent pitometer connections are then so placed at various points on the service mains throughout the large permanent district that this can at will be divided into smaller divisions of only a few blocks area each.

The study of these is then taken up in detail, the work of isolation and subdivision being done between the hours of 11 p. m. and 5 a. m., when the flow is most uniform, least annoyance is caused the citizens, and, in residence districts, there is practically no legitimate use of water.

A rod pitometer without recorder is set up at the connection on the main supplying the small district under examination, sheltered by a small portable house, and left in position so long as may be necessary to complete the work.

During the daytime all mains supplying the district are left open, and there is no interference with full supply for fire protection. At 11 p. m. the survey party arrives on the ground and at once proceeds to isolate the district by closing all controlling valves except the one on which the pitometer is placed; this having been done, this main is closed for a few minutes and the isolation of the district so tested.

Having re-opened this main the operator notes the deflection in the pitometer U-tube and from this calculates the total rate of flow into the district; in the small districts the deflection is usually so slight that the flow is artificially increased by partially opening a fire hydrant until the U-tube shows a reading of 6 or 8 inches: this is particularly desirable in facilitating the subsequent operations, as the sensitiveness of the instrument increases rapidly with increased velocity of flow in the main.

Having reached this point the work is taken up in final detail as follows:

The pitometer U-tube showing a deflection of some 6 or 8 inches, a section of main supplying a single block is cut off, the drop at the pitometer noted, and the flow to this short section at once calculated.

The water is then at once turned on, and an inspector and party furnished with aquaphones proceed to test for flow each service pipe supplied from the short section of main under test; this test is made by placing an iron rod on the curb stop cock of each service, when, by the

use of the aquaphone, a flow of water, even if slight, can be detected by sound. The men soon become remarkably expert in this work.

Where flow is noted the curb cock is closed; if this stops the flow the same is evidently caused either by waste within the house, or by a leak in the service pipe on the house side of the curb cock: if it does not stop, the leak is probably between the main and the curb.

Having so far as possible accounted for or stopped all service pipe flow, test is made by pitometer reading to determine the amount of water still flowing into this short section of main; this remainder is then due to main leaks, leaking valves, or unrecorded service connections, and is taken up in detail later.

This practically ends the night work on this section, until the tests are repeated after corrective measures have been taken.

Where doubt exists as to whether service pipe flow is due to leaking fixtures or to defective service pipe a daytime inspection is at once made; at this time examination is made of all house fixtures; if these be tight and the aquaphone still indicates flow means are at once taken to have necessary repairs made to the service pipe.

If leaking fixtures are found they are reported to the Water Registrar whose inspectors follow the matter up and see that the householder complies with the regulations.

Where the night survey indicates a probable leak in the main itself, a sharp-pointed steel rod is worked down until it rests against the main, and test made by aquaphone: this is repeated at intervals along the line and usually soon locates the source of the trouble.

In general, surveys and tests are repeated until practically all of the water flowing into the district is accounted for.

The method of waste detection outlined is sufficiently simple, but many embarrassing difficulties are encountered in carrying it out, and there is ample opportunity for the men in charge to exercise any amount of patience and ingenuity.

There are unrecorded services supplying a number of houses which should be, but are not, directly connected with the main.

Fluctuations in the rate of flow are inevitable and cause confusion and wrong deductions.

Un-recorded cross-connections between mains and between service pipes cause much trouble.

Leaking valves are not uncommon.

Curb cock boxes are covered over, broken, or filled with rubbish—and sometimes with cement; and other troubles, too numerous to mention, are always cropping up.

In spite of all this the results obtained, as indicated below, are gratifying and more than justify all the expense and trouble involved.

During the five years that this work has been in progress the underground leaks found and closed—not including any waste, above the ground surface—aggregate over twenty-five million gallons a day. Comment on this seems unnecessary.

A very large proportion of the leaks were found in the house service pipes, many of which are of wrought iron laid years ago and now without exception badly corroded.

The following brief summary of work done during the year ending June 30, 1910, may be of interest.

	NUMBER	WASTE GALLONS PER DAY
Service pipes inspected	34,267	
Houses inspected	21,642	
Houses with leaking fixtures	3,305	
Abandoned services and taps leaking	11	305,000
Iron services broken	204	2,438,000
Lead services broken	87	1,202,000
Wiped joints broken	74	710,000
Couplings on services leaking	18	119,000
Curb cocks leaking	30	85,000
Taps blown out	3	50,000
Joints on mains leaking	92	1,034,000
Mains broken	2	332,000
Valves leaking	11	89,000
		6,364 000

This includes no leaks or breaks detected by reason of water appearing on the surface of the ground.

Our system of records is rather comp ete and includes all necessary maps, showing the distribution system in detail, and card records of existing permanent installations and of all data as the same is collected.

The result of this work together with that of the installation of some 15,000 small meters has been the reduction of the mean total daily flow from 67,500,000 gallons to 59,000,000 gallons, and of the per capita from 217 to 178 gallons. This in a period of five years, when the increase of population amounted to about 30,000.

The total annual cost of the work as at present organized is about $25,000.

STRIPPING RESERVOIR SITES AT NEWCASTLE, ENGLAND

By H. G. Coventry

The Font Reservoir has a capacity of 721,500,000 gallons, with a top water area of eighty-nine acres, and a depth at the dam of eighty feet.

The watershed area above the dam is eleven square miles, and consists almost entirely of moorland, grass and heather with large areas of peat, so that the water is very much discolored during the rainy and winter periods.

The area covered by the reservoir was not stripped, but in the autumn of the previous year to the filling of the reservoir, the grass was mown down and the area partly fired.

The reservoir commenced to fill on March 4, 1908, but was not full until December of the same year. The water from the reservoir can be drawn off at six different levels, about twelve feet apart, the top draw-off being five feet below top water, and there is a washout at the bottom of the reservoir. From the commencement of the filling the water was used for supply, about one and three-fourths million gallons per day, and no trouble was experienced either by taste or smell from the water, although a very large amount of organic matter must have been present in the reservoir.

Owing to the completion of some work in the outlet tunnel, the washout from the bottom of the reservoir was not opened until the seventh of July or about four months after the filling of the reservoir. The reservoir at that time having a depth of fifty-seven feet, the water from the washout had a very strong smell and looked the color of ink, while a number of dead trout were found within about a quarter mile of the works, evidently poisoned by the putrid water discharged from the washout into the river. On comparing the water from the washout with the water used for supply from the top of the reservoir in an eight-inch Tintometer Tube, the following results were obtained:

	YELLOW	RED	BLUE
Water from bottom of reservoir	20.0	10.0	4.0
Water from top of reservoir	7.0	1.9	

A week later the following results were obtained:

	YELLOW	RED	BLUE
Water from bottom of reservoir	12.0	4.4	2.0
Water from top of reservoir	6.0	1.7	0.2

I cannot lay my hand on the exact date, but it was not until some two months later that the water from the bottom and the top of the reservoir was of practically the same color, the washout discharging one and one-half million gallons per day. I may mention that the washout is always open to discharge compensation water so that there is always constant circulation from the top of the reservoir to the bottom, the water for supply being always taken from the topmost draw-off.

Very soon after the washout was opened it was noticed that a thick red fungoid kind of growth had formed all over the invert of the tunnel, when covered with water, the invert being of hard blue Staffordshire brick work. This growth although cleaned off several times, formed immediately again, and about the twenty-fifth of August ceased to appear, and has not appeared since, the smell from the water also ceased to be noticeable at about the same date.

No trouble has been experienced with the vegetation round the reservoir, which was practically all killed the first year the reservoir was filled, and as the reservoir lowered the dead vegetation when dry, was fired.

HIGH PRESSURE FIRE SERVICE COMPARED WITH PORTABLE FIRE ENGINES

By Charles A. Hague

About 1866 a direct system of water supply had been built and put into operation in which water was distributed through pipes laid in the streets, for the purpose of protection against fires. By a direct system is meant a closed circuit of water pipes wherein the water pressure is raised and maintained at a certain point, and where there is no storage of water, aside from what is contained in the pump well or supply main, and the supply flowing thereto. The first of these direct systems was established at Lockport, N. Y., by Birdsill Holly, and contained a mile of cast iron water pipes with rotary pump operated by turbine water wheels. Two years later a similar system was built at Auburn, N. Y., in which a domestic supply was combined with the fire protection; both these systems were driven by means of water power. The enlargement of such an important idea soon carried it beyond the reach of a single means of applying power and that means such a restricted one; so that before long the question of the application of steam power which could be located almost anywhere, came naturally enough into the proposition. In later years, or at the present day, the original special fire protection system apart from the domestic supply, along the lines laid down in 1866 has returned to us, but now, as is consistent with the spirit of the times, the power applied is through the medium of steam, water, gas, or electricity.

The first attempt at the use of steam power for this kind of water supply and fire protection, somewhere late in the sixties, was in the form of a steam engine driving a line shaft and from this shaft there were driven a series of gang pumps consisting of single acting plunger pumps. In conjunction with these gang pumps there was used a rotary pump known as the Holly Rotary Pumping Engine and Fire Pump. Thus development continued until a good many cities in the flat districts of the Middle West were equipped with this combination of domestic and fire service water works plant, and some are still operating this form of service.

But as cities grew larger and larger with the development of the country during the seventies and eighties, the practicability of the double system began to be doubted, and a moderate uniform water pressure for the regular domestic supply and the use of portable steam fire engines taking their supplies from the mains at the domestic pressure, gradually took form and gained headway. Today in many cities the steam fire engine plays a very important part in fire service.

PRESSURE IN THE MAINS

With a uniform pressure in the mains or nearly so, and without raising the pressure for fire alarms, the steamers acting as portable relay stations take the water from the mains at whatever pressure they can get, and produce sufficient force to cover the hose friction and furnish effective fire streams at the point of need. In the absence of dead ends, and with good circulation the flow of water in the "gridiron system" will equalize fairly well, but with heavy draughts and with restricted circulation, fire service sometimes suffers very severely from lack of water supplies, and it must be remembered that nearly all disastrous fires have been the result of an inadequate supply of water with which to fight the conflagration.

A case recently coming within the experience of the writer, in a moderate sized city, gives an example of fairly good results as to the equalization of the water pressure within the mains and is given herewith:

NUMBER OF THE HYDRANT	NORMAL PRESSURE	HIGHEST PRESSURE	LOWEST PRESSURE
1	50	55	30
2	55	60	40
3	55	63	30
4	55	63	45
5	55	65	40
6	55	80	45
7	55	60	45
8	50	60	40
9	50	60	40
10	55	55	45
11	55	60	35
12	60	65	50
13	55	60	50
14	60	60	58
15	60	65	58
16	65	68	58

The pressures in the hydrants during these experiments took place during the busy hours of the day, and at sixteen hydrants in the business section of the city were as in the accompanying table. While these tests for pressure were being made at the various hydrants it was perfectly evident when hydraulic elevators connected with the water mains in the business districts were put into operation and when they were shut off again. The drops in the pressure from the starting of the elevators, although not very serious either in range or duration, were nevertheless plainly noticeable, but the absence of water hammer or water ram, when elevators were shut off, gave clear evidence of the excellent circulation and the absence of dead ends in the pipe system.

Hydrant no. 16 was taken as representing the pressure at the nearest practical point to the main distributing reservoir, at as nearly as possible the same elevation as the others in the immediate business district. No. 16 was taken as a standard from which to note the loss in pressure in the water flowing to and through the mains supplying the city. Then corrections were made for difference in elevations, and readings obtained which show the net difference or loss in pressure necessary to flow the water from the point on a 30-inch main where no. 16 was located to the various hydrants where the pressures were noted in the congested district. The following table gives the net loss in pressure between no. 16 and the hydrants named:

Table of Pressure Losses

HYDRANT NUMBER	LOSS IN POUNDS	HYDRANT NUMBER	LOSS IN POUNDS
1	10	9	10
2	5	10	5
3	5	11	5
4	5	12	0
5	5	13	5
6	5	14	0
7	5	15	0
8	10		

The results of these experiments and tests indicate a very satisfactory condition of affairs regarding arrangement of the distributing mains and the actual flow of water through them throughout the business district and heart of the city during busy hours.

To reach a conclusion as to the effect upon the water pressure and quantity of water within the principal mains which would be pro-

duced by the operation at full speed and capacity of five steam fire engines, the drop in pressure was ascertained by calculation, in addition to that already shown at the several hydrants, necessary to produce a flow which would easily and safely supply the five engines. The table below gives the principal dimensions of the five steamers in the fire department actually considered:

Table of Dimensions of Steam Fire Engines

Second size La Franc, vertical.
Boiler 32 x 60 inches.
Two steam cylinders, each $7\frac{3}{4}$ inches diameter.
Two double acting pumps, plungers each $4\frac{5}{8}$ inches diameter.
Stroke of all, 8 inches.
Second size American, vertical.
Boiler 34 x 64 inches.
Two steam cylinders, each 8 inches diameter.
Two double acting pumps, plungers each $4\frac{3}{4}$ inches diameter.
Stroke of all, 8 inches.
Second size Amoskeag, vertical.
Boiler 32 x 64 inches.
Two steam cylinders, each $6\frac{7}{8}$ inches diameter.
Two double acting pumps, plungers each $4\frac{1}{4}$ inches diameter.
Stroke of all, 8 inches.
Second size LaFranc, vertical.
Boiler 33 x 62 inches.
Two steam cylinders, each $7\frac{3}{4}$ inches diameter.
Two double acting pumps, plungers each $4\frac{5}{8}$ inches diameter
Stroke of all, 9 inches.
Third size Silsby rotary, horizontal.
Boiler 34 x 58 inches.
Two rotary cylinders, each $10\frac{5}{8}$ inches diameter.
Two rotary pumps, each $5\frac{3}{4}$ inches diameter.
Centre to centre, 7 inches.

In order that the test of the mains for the fire service might be as exacting and severe as practicable, the first calculations were made with reference to the five steamers being attached to five fire hydrants in the central square, the very heart of the business section, and where the hardest fire service would naturally fall. This square is formed by the widening of the two principal streets at their intersection, and the hydrants are well distributed about the sides of the square at intersecting streets. It was found that a drop in pressure at these hydrants of 10 pounds would cause a flow and supply of 2849 gallons per minute, leaving at the hydrant a working pressure for the steamers of 45 pounds with the water flowing to the engines.

This supply of 2849 gallons per minute brought by the moderate drop of 10 pounds below normal pressure is obtained as follows:

259 g.p.m. through 3,150 feet of 6-inch pipe.
586 g.p.m. through 1,050 feet of 8-inch pipe.
761 g.p.m. through 600 feet of 8-inch pipe.
1,243 g.p.m. through 300 feet of 8-inch pipe.

2,849 g.p.m. total delivery.

The delivery capacities of the pipes leading from the large 30-inch and 16-inch supply mains from the reservoir, to the points of distribution supplying the central square are as follows:

1,200 g.p.m. through 600 feet of 10-inch pipe.
1,248 g.p.m. through 487 feet of 10-inch pipe.
497 g.p.m. through 1,837 feet of 8-inch pipe.

2,945 g.p.m. total delivery.

The above rates of flow were calculated by means of the well known "Kutter" formula, an authoritative formula used extensively by hydraulic engineers in this country and in Europe for ascertaining the flow of water in pipes and conduits. The quantities given take into account the diameters and lengths of the pipe, and the loss of difference in pressure in the direction of flow; these differences being taken from the test observations while the city was being regularly supplied with water, the delivery for fire purposes being an addition to the regular domestic supply. The results given are safe and conservative and no doubt afford considerable leeway. Aside from the flow through the mains considered, there are several auxiliary mains which have not been included on account of their indirectness, but which would nevertheless add a liberal percentage to the flow noted as due at the central square under the conditions stated. The Kutter formula follows:

$$\text{Mean velocity in feet per second} = \frac{41.6 + \frac{1.811}{n} + \frac{0.00281}{\text{Slope}}}{1.0 + \left(41.6 + \frac{0.00281}{\text{Slope}}\right) \times \frac{n}{\sqrt{\text{Mean Rad.}}}} \sqrt{\text{Mean Rad} \times \text{Slope}}.$$

All dimensions in feet.
n = coefficient of roughness of pipe = 0.011.
Slope = loss of head divided by length of pipe.
Mean Rad = $\frac{1}{4}$ diameter of pipe.

The hydrants nos. 1 to 14 inclusive, distributed along five or six city blocks, by the use of pipes and mains coöperative with those already mentioned will in this particular "gridiron" furnish from 5000 to 6000 g.p.m. available for steam fire engines at the various hydrants with a very moderate drop in pressure, and in a city of the size and population referred to, its buildings seldom going more than five or six stories in height, such service need not be replaced by the high pressure special pipe system with a central station. Where the regular street mains can be practicably used to such an effective extent, and with the moderate investment called for by steam fire engines, and chemical apparatus, municipal corporations would hardly be justified in investing in the modern direct fire system, so costly in construction and sometimes so expensive in operation.

The city referred to herein is what would be called a comparatively small one, but a unit system of fire engine protection established in a much larger community, and repeated as required to cover greater territory, would produce equivalent effects in fire service. The line of demarcation between high pressure centralized fire protection, and the steam fire engine, is found where the buildings above six stories in height are abundant, and concentrated, and where great risk to human beings and valuable property is imminent and apparent. The extent of territory covered by a city is not a telling factor in favor of high pressure service. It is concentration and loftiness of construction that menaces. Even where the high pressure service is justified its use is a distinct class of work, requiring experience and great judgment in order that a greater property loss be not imposed by excessive use of water than the total destruction of the particular property involved in the blaze, would entail. This may be readily comprehended by considering the possibility of confining the fire to the original building but flooding with water several basements and cellars filled with valuable property at each side of the fire.

IMPROVING THE DISTRIBUTION

In cities containing six story buildings and less, cities which have outgrown original gridiron systems, and suffering from lack of adequate extension from time to time, of the street mains, especially with reference to fire protection, may greatly improve their steam fire engine service by revamping the pipe system to correspond to the enlarged requirements caused by growth. Such an improvement in the gridiron will greatly enhance the effectiveness of distribution;

permitting liberal water supply and concentration of steamers at factory fires at the outskirts of the town. An example is given below of how a change in the map will remedy unsatisfactory water pressure. The average pressure at the hydrants during the busy time of day was 21 pounds before the improvement and 31 pounds after the change in mains; showing a gain of 48 per cent in pressure with a much greater volume of water flowing. That the effect of such a change upon the value of fire service is very important, goes without saying, and this improvement in pressure and volume was supplemented by locating in the business and manufacturing districts, additional fire hydrants, 250 feet apart. The general scheme was accomplished by remapping the city, and making an entirely new layout of principal mains, with the idea of placing the most needed at once, and then in the future whenever replacements or extensions were called for, following the map so that in time an entirely new distribution would be effected. The table showing the changes in pressure follows:

HYDRANT	RECORD OF PRESSURE BEFORE LARGER MAINS WERE TURNED ON; POUNDS PER SQUARE INCH	RECORD OF PRESSURE AFTER LARGER MAINS WERE TURNED ON; POUNDS PER SQUARE INCH	HYDRANT	RECORD OF PRESSURE BEFORE LARGER MAINS WERE TURNED ON; POUNDS PER SQUARE INCH	RECORD OF PRESSURE AFTER LARGER MAINS WERE TURNED ON; POUNDS PER SQUARE INCH
1	26	38	16	20	35
2	25	37	17	18	33
3	26	38	18	14	27
4	27	30	19	16	26
5	26	28	20	18	30
6	20	29	21	19	36
7	23	30	22	23	37
8	23	31	23	19	36
9	26	32	24	17	29
10	21	26	25	21	31
11	27	34	26	17	28
12	19	32	27	25	34
13	20	33	28	27	34
14	22	36	29	23	33
15	20	35	30	29	32

THE STEAM FIRE ENGINE

Another important step in this matter is to ascertain the full capacity of steam fire engines and what it would be necessary for them to do to ensure proper fire protection in the most valuable districts of a city. The ordinary method of computing the delivery

capacity of steam fire engines by the area of the plungers, length of stroke, and revolutions per minute is not altogether reliable, as when forced up to an excessive speed the pumps cannot fill solidly with water. In fact it is possible to cause an engine to "run away" from the water and so make the motions without pumping the corresponding amount of water. With the plunger engines hereinbefore given, the usual speed at which the department operates these machines is from 134 to 200 r.p.m. and the latter speed ought to give about the best work of which steamers of the size indicated are capable. Such engines may be run up to 500 r.p.m. and sometimes are, but such a rate is entirely too high for proper work.

Taking the largest of the five mentioned, for each revolution there will be a delivery of $2\frac{1}{2}$ gallons of water provided there is no lost action or "slip" in the pumps. Of course there is lost motion in the pumping, increasing as the speed increases, but it is not practicable to determine it closely, so it may be neglected as a direct application but allowed for to a moderate extent in determining the probable number of revolutions per minute at the higher capacity. But aside from the performance of the engine itself and whatever its operation may signify, the actual delivery of water from the hose nozzles, its pressure at the nozzles, the distances and heights to which it can be thrown and the force with which it may be sent into a fire, are much more vital factors than any relation which the running of the engine may bear to its presumed execution.

All pumping machinery slips or churns the water more or less in every day operation. This loss varies from a $\frac{1}{2}$ of 1 per cent in the large slow moving pumping engine, to 30 per cent in rapid pumping engines of other types. A steam fire engine under rapid motion would reach 10 per cent slippage and yet deliver apparently solid water. This means an effective delivery of 90 per cent for the fire engine under heavy rapid work, and $99\frac{1}{2}$ per cent for large slow moving pumping engines in water works stations, the efficiency herein meaning the efficiency of the pump end of the machine actually delivering water as against a mathematical displacement represented by the dimensions and mechanical motions of the plungers. Steam economy does not figure in the fire engine, as the absurdity of reaching after steam and fuel economy for a few hours' work with a half million dollar fire loss threatening, is apparent without much study. What is required of a steam fire engine is to deliver a large quantity of water without running at such speed that a large percentage of its power is lost in opening and closing the pump valves

and by-passing the water through them; and it is also required that it use its power in sending out a large quantity of water under a moderate pressure at the nozzle, the nozzle being of liberal size; rather than producing a great water pressure at the pumps by using a small nozzle.

The flow or projection of water under a head or pressure, whether from fire engines or direct high service, follows the law of falling bodies, or the law of gravitation. If an opening in a standpipe near the ground were so situated that there were a hundred feet head of water above the centre of this opening, the velocity of the issuing water would be theoretically equal to the velocity of a cannon ball falling through space from a height of a hundred feet; that is, theoretically, the velocity of the water coming out of the opening would be just equal to the velocity of the cannon ball at the instant it passes the centre of the opening after falling a hundred feet.

This law is expressed by the formula:

$$V = \sqrt{2gh}$$ in which,

V = velocity in feet per second.
g = acceleration of gravity and = 32.2 and $2g$ = 64.4.
h = head of water in feet.

Then if the head is 100 feet, the velocity of the jet or of the falling cannon ball would be in feet per second, equal to the square root of 64.4×100.

$64.4 \times 100 = 6440$ and the square root of 6440 is 80 very nearly; disregarding fractions.

Therefore the water would issue theoretically, or the cannon ball would have a velocity in falling at the instant it passed by the opening in the standpipe, of 80 feet per second. When we know the area of cross section of the opening, the rate per second readily indicates the quantity of water projected.

It has been found, however, that the actual discharge of the water is somewhat less than the theoretical, on account of contraction of the jet at the opening, effects of atmospheric resistance and other factors. But numerous scientific experiments, practical observations when delivery is made into tanks or bodies of water of known capacity have fixed the practical limits of the percentage of discharge realized; from such data we have a means of determining the actual discharge from a hose nozzle regardless of the operation of the fire engine or other source of supply, producing such delivery.

With regular $2\frac{1}{2}$-inch rubber lined fire hose, 300 feet, 80 pounds

pressure at $1\frac{1}{8}$-inch smooth bore nozzles, two lines will deliver 540 gallons per minute, and the work will call for 170 pounds pressure at the steamer. For 400 feet of hose in each line, 210 pounds pressure would be required at the steamer; and for 500 feet, there would be needed 240 pounds. Such streams would go into a six story burning building at an elevation of 100 feet with great energy, and a steamer of the largest dimensions herein given ought to deliver such a quantity of water at a speed of 240 revolutions per minute allowing 90 per cent efficiency of the pumps.

In comparison, the deluge of water delivered by the modern high pressure system may be noted by observing that with a $2\frac{1}{2}$-inch nozzle, 400 feet of 4-inch hose, a hydrant pressure of 288 pounds and a nozzle pressure of 80 pounds, 1050 gallons per minute would be delivered from a single pipe; and with 100 pounds nozzle pressure, 1200 gallons per minute would be discharged under similar conditions. Such enormous quantities and pressures indicate at once how out of place such systems would be in the smaller cities with buildings not exceeding say six stories in height, and even in the larger cities such forces need to be used with good judgment, often merely held in reserve. The presence, within immediate call, of such fire fighting facilities although if not always called into play, affect insurance rates favorably to the policy holders, and materially reduce the risks to the insurers.

Five steamers under the fire engine conditions previously referred to, would deliver 2700 gallons per minute, and this would mean 10 streams from $1\frac{1}{8}$-inch nozzles, smooth bore, with a pressure at the pipe ends of 80 pounds and would discharge at the rate of nearly four million gallons per 24 hours, which would fill a reservoir 250 feet square, 9 feet deep, a quantity seldom thrown upon a fire in cities of the size referred to.

With two lines of hose, each 300 feet long, with $1\frac{1}{8}$-inch nozzles, both lines will deliver 600 gallons per minute, and the work would call for 215 pounds pressure at the steamer, the engine making 266 r.p.m. Five steamers would deliver 3000 g.p.m. and such quantities of water thrown upon a fire with the buildings of the general dimensions usually found in the smaller cities, would be simply prodigious in proportion to the real needs, and insurance companies would no doubt cry out for the payment of premiums against water damage instead of against fire. In this connection it may be of interest to note a practical range of pressures, quantities, and hose lengths, for steam fire engines probably found in fire service.

Regular 2½-inch rubber lined fire hose, and standard 1⅛-inch smooth bore nozzles.

Water Pressure at the Steamer for Different Lengths of Hose.

PRESSURE AT THE NOZZLE	QUANTITY DISCHARGED	100 FEET	200 FEET	300 FEET	400 FEET	500 FEET
Pounds	*U. S. gallons*					
50	210	66	82	97	113	129
60	232	79	98	118	137	156
70	250	92	115	137	160	182
80	269	106	132	157	183	209
90	285	119	148	177	206	235

Tests on long lines of hose show that steamers with 300 pounds pressure on their pumps, 1000 feet in a single line of hose, 1⅛-inch smooth bore nozzles, with a nozzle pressure of 70 pounds will deliver 260 gallons per minute. In such work the friction loss in the hose is 190 pounds per square inch.

The quantity of water actually thrown upon a fire is very much less than is generally supposed, as will be seen when the counting of revolutions is considered. A locomotive traveling a mile a minute with 6½-foot driving wheels, will make 260 r.p.m. There are four exhausts from the cylinders at each revolution, or 1040 per minute, or 17 to the second, and the effect upon the ear is something like the roll of a drum so rapidly do the beats follow each other. It is next to impossible to count the revolutions and requires a great deal of practice to do such counting by sound. Therefore when we walk down the street where a fire engine is at work, if the exhausts are distinctly distinguishable from each other, it may be depended upon that 200 revolutions is somewhat above the real motion of the machine. Then consider that 300 r.p.m. means 1200 exhausts or 20 per second, and it will be seen how easy it is to be mistaken even in the speed, to say nothing about the actual delivery of water at such speeds. Again, 500 r.p.m. means 2000 beats per minute or 33 per second for the ear to catch and articulate.

The modern steam fire engine mounted upon wheels for ready transportation to the place of usefulness, represents an extremely interesting combination of several distinct lines of engineering and construction. The running gear alone is a problem. A good deal of study and experience were passed through before that portion of the apparatus, which to the layman looks very much like a set of ordinary

wagon wheels, had reached a point at which reliable transportation was assured, and before hubs, spokes, felloes, tires, axles, springs and appurtenances were strengthened and proportioned to carry safely, from two to four tons of weight at the highest attainable speed of three powerful and excited horses, passing over and through any and all obstructions at a rate of motion sufficient to wreck any ordinary running gear carrying a quarter of the load.

Then, the development of the steam boiler to give so much power with so little weight, combining quick initial steaming with fairly good staying qualities when at work, represents boiler making as a high art.

The peculiar adaptation of the steam engine, occupying so little space, giving such proportional high power with so small an amount of material. This phase of the steam engine although not especially high in economy, is nevertheless an exponent of the highest qualities in material and workmanship, with the minimum of weight to be carried is so earnestly sought in combination with the utmost staying qualities in the face of the most appalling danger known to civilization, where terror is so prominent and where glory is so inconspicuous.

Then last but preëminent, comes the hydraulic end of the machine. And here indeed, the science and art of the designer and manufacturer are put to their trumps. Water is just about as stubborn to handle under bad conditions as molten lead. Besides it will freeze and saturate and ram and jar and do all sorts of objectionable things when beyond proper management, but it is a most obedient, helpful and friendly servant when properly controlled. The fire engine pump is one of the highest developments of hydraulics, and a subject well worthy of the efforts of the greatest ability in that line of work. It is not imposing to look upon but it has great powers of achievement consisting mostly in its ability to get the water in, and then out again under high pressure, taking its supply either from the pressure of a street hydrant, or up through the length of a 20-foot suction hose, and then putting this water under a pressure of 300 pounds and sending it through a thousand feet of hose to a fire nozzle. The continuous and successful performance of such trying work, with such limited dimensions, is most admirable evidence of how well conditions imposed may be met by competent and experienced designing.

THE CHEMICAL FIRE ENGINE

Chemical fire extinguishers came into the field some years ago, and this form of fire apparatus has been extensively developed. The writer distinctly remembers his first contact with this form of fire engine some twenty-five years ago, in the preparation of drawings for the use of an inventor of the apparatus. The machine resembles a large ornamental hose carriage with two highly polished copper cylinders about the dimensions of ordinary kitchen boilers, arranged horizontally at each side just below and to the rear of the hose reel. The apparatus on wheels came along as a natural sequence to the well known Babcock Fire Extinguisher, the first of the chemical devices designed to smother a fire by the use of carbonic acid gas.

In the larger sizes of the early types, there are two horizontal tanks of heavy polished copper, bolted to wrought iron or forged steel frames and braced to each other. The hose is carried on an automatic reel generally mounted at the highest point of the machine upon the frame arch or "crane neck." The acid-chamber lined with glass is placed above the tanks, the latter being fitted with agitators turned by handles at the outside, for thoroughly mixing and dissolving the soda. The discharge pipes of the tanks were made as short and straight as practicable, usually without bends, thus permitting the free and unrestricted flow of the charged water to the hose upon the reel.

These double tank engines were arranged to give a continuous stream without moving the hose; while one tank was being discharged the other was replenished and so worked alternately; or, both tanks could be worked at the same time, thereby providing two streams.

The automatic hose reel is connected to the tanks by a short pipe and the hose attached to it, so that by the use of this form of reel, the hose is always ready for instant service as the solution passes from the tank into the reel, and through the hose; it being only necessary to unreel the required length of hose to reach the fire, the balance remaining on the reel, thus avoiding delay of unreeling the hose and attaching it to an outlet coupling as on a steam fire engine.

In these days of the automobile the use of chemicals has come largely into favor, with especial reference to the smaller cities and the outlying districts of the larger cities, resulting in the rapid development of the motor-chemical car. Many of the larger cities such as Philadelphia, Boston, Baltimore, Chicago and others use chemical engines regularly in the department for general service where they

are adapted in large areas of buildings of moderate height and where the fire may be quickly gotten at. Chemical engines are not used in the Boroughs of Manhattan, Brooklyn and Bronx of New York City, but are employed to a limited extent in the Boroughs of Queens and Richmond. In the congested districts of large cities its usefulness is sometimes doubted, probably on account of the overcrowded conditions, and the great headway generally obtained by a fire at early stages before discovery, where large masses of combustible material are concentrated in minor and moderate sized manufacturing establishments, locked up for the night and not closely watched. The early or incipient stages of a fire are where the chemical engine or any form of chemical extinguisher finds its usefulness. Beyond a certain point of heat, and burning masses of combustibles, the chemical apparatus is powerless.

Wherever it can be employed the chemical type of apparatus reaches the fire quickly, and is used with great success in a good many cities. Its use will likely increase rapidly in its present automobile form as time goes on. Where it is appropriate it extinguishes a goodly percentage of the fires at the early stages, and it may be noted that this type of fire fighting machine comes nearest to affording what might be termed the scientific handling of fires, which means chiefly, getting directly at the location of a blaze and using just sufficient of the suppressing element to do the work, thereby avoiding to a great extent the damage inflicted by too much water as frequently happens in larger fires. But with the chemical machine it is absolutely necessary to catch the fire in its incipiency, and the autocar lends itself admirably to this branch of service, as it gets to the scene of action with marvelous quickness, and as now constructed, with a comparatively large supply of particularly effective fluid, a fluid in which deadly quality rather than great quantity is depended upon.

However, when the fire reaches a stage before discovery or despite the most persistent attempts with the chemical apparatus to extinguish it in its incipiency, and it is necessary to combat the blaze with more powerful efforts, the steam fire engine comes into play in districts where the buildings do not exceed say five or six stories, and where streams from $1\frac{1}{8}$-inch smooth bore nozzles with a unit delivery of 250 gallons per minute can be effectively used, and then water, and plenty of it must be used as the necessities of the emergency require.

Fires in five or six story buildings with—say fifty feet of frontage—are encountered in many of the smaller cities and require practically

as heroic treatment in one place as in another, with the difference that in a small or moderate sized city the proportionate danger of a disastrous conflagration is much greater, for the reason that the fire department available and the number of steamers at command are in proportion to the population and business importance of the community, while the safeguard against fire is only in proportion to the fighting force, and is only effective up to the balancing point where the efforts of the department are sufficient to cope with the threatening danger. In many cities where ten fire engines mark the limit of the department, a fire could easily occur which would require thirty steamers to ensure prompt extinguishment of the flames. And such a fire getting beyond control with high winds, would mean the conflagration which every now and then visits various communities.

New York could concentrate thirty fire engines at work well within an hour, and repeatedly did so before the installation of the high pressure service, for what might be called a moderate fire for New York, but what would be called a threatening fire for small cities. At Baltimore, according to records, it seems that at least twelve hours elapsed from the breaking out of the fire which made such a wasteful destruction several years ago, before a sufficient force was available to have provided against the spread of even the initial fire.

But with all of the fire engine safeguards possible to have at hand, and however effective they may be in a city of great area but with buildings of moderate height, a time seems to have arrived when the immense aggregation of values, and the lofty buildings of today together with their contents, concentrated within the commercial districts of metropolitan cities, the chances of conflagrations with their excessive losses, of life and property and disastrous effects on business enterprise, point to the necessity of providing the best practical means of prevention and defense against such possible calamities.

HIGH PRESSURE FIRE SERVICE

The problem of furnishing protection against the ravages of fire in the business districts of large cities can hardly be overestimated in importance, involving as it does public safety and great financial considerations. It is a problem which is strongly attracting the attention of insurance companies on account of the great losses sustained in such districts, which ultimately react upon the value of investments

in the bearing of insurance rates. The modern "sky scraper" in business centres, and the concentration of enormous values in less imposing buildings, brought about by the present-day scale of operations, have necessitated special means and efforts for fire fighting. This all means heavy pressures, up to 300 pounds per square inch, and great volume of discharge up to many thousands of gallons per minute.

And so history repeats itself in this line, as it has and does in many others, the repetition, however, being brought about by entirely different conditions from those attending the initial installation of direct fire protection, although the economic instincts were present both in the old and the new. Fire and domestic service were at first combined in the same system, where direct fire service was provided by the mains, the domestic demands outgrew and crippled the fire service, and thereby forced the use of auxiliary protection in the form of fire engines, until today, the immense concentration of property brings back to us the isolated, special system of mains used only for protection against and extinguishment of fire.

The present day feature of high pressure mains for fire service was first brought into use in some of the lake cities where large bodies of fresh water furnished unlimited supplies for the purpose. Cleveland, Buffalo, Detroit, Chicago and Milwaukee employed such a system, but instead of pumping stations on shore, put the fire boats to such uses, by coupling onto the mains at the nearest practicable point to the fire.

Systems of high pressure water mains for fire service exclusively are installed in New York, Philadelphia, Toronto, Winnipeg and other cities, while San Francisco and Baltimore are now putting in such systems. Philadelphia has used its system for about eight years and Greater New York about three years. Even in this short time experience in these cities establishes the feasibility of the separate high pressure service and its superiority over the regular steam fire engines in the thickly and loftily built up sections of the larger cities. The tendency not to say the necessity of the modern fire department in the large cities, where excessively high buildings are in vogue, is the use of large, energetic, penetrating streams. A stream of such dimensions and volume requires under the best conditions, one or two of the largest size, or two, or maybe three smaller engines, working up to full capacity, while one hydrant on a properly equipped high pressure system can supply five such streams.

Another advantage of the high pressure system is that the high pressure companies responding on a first alarm, can handle a fire

which under the fire engine practice would require second or third alarms. The high pressure companies are able to obtain and handle in the early stages of a fire, as many streams and as much water as could be gotten from fire engines responding to first, second and third alarms. From the time of receiving the first alarm until the arrival at the fire of an official, his determination as to the necessity of sending in a second alarm, and the getting to work of the second alarm engines, twelve to fifteen minutes might and frequently do elapse. The high pressure service will save this valuable time at the early and most vital stages of fire fighting.

In the thickly built up area of a metropolitan city, where buildings exceeding six stories in height are frequent, where great aggregations of values exist, and where large numbers of human beings are massed, the high pressure fire protection system finds its field of usefulness. A large number of powerful streams can be concentrated upon a fire in much shorter time, with fewer men and much less apparatus than with fire engines. It can deliver its full capacity at any point in the district covered by its mains, at any desired pressure, and can sustain this pressure any length of time desired. It removes or prevents the confusion resulting from the operation of a large number of fire engines, tends to prevent the misunderstanding of orders and in every way simplifies operations.

The design of a high pressure fire protection system should provide for a fire proof pumping station, properly protected and located so as to be free from the risks of a sweeping conflagration. It should be equipped with pumping machinery of not too great unit capacity, and of sufficient aggregate capacity to meet the predetermined requirements with adequate reserve; the pumping units to be capable of operation under a pressure of 300 pounds, and delivering into a gridiron system provided with properly gated divisions and connection; arranged so as to be free from dead ends. The distributing system to be connected with the pumping station by means of duplicate supply mains, and to be so designed as to deliver the full capacity about any block or square within the area served without undue loss of head from friction. No pipe to be less than 12-inch diameter and to be connected at all intersections.

Connections to be provided so that fire boats where available, may be used in connection with the system, and the mains so provided with gate valves so placed that sections, not to exceed 500 feet of pipe, may be cut out at any time. Fire hydrants to be of liberal dimensions, with four independently gated hose nozzles, connected

to the mains by 8-inch gated branches, and situated so that the area served by each hydrant shall not be more than 40,000 square feet.

High pressure fire systems, like the regular water works construction are governed by local conditions, and the only items so far approaching anything like standardization are:

Hydrants: Four 3-inch outlets, calculated to serve four 2-inch streams giving 85 per cent of the theoretical discharge at 80 pounds nozzle pressure, delivering approximately 900 gallons per nozzle minute, or from 3600 to 4000 gallons per hydrant minute.

So far as the fire department is concerned with the high pressure system, the initial apparatus, and taking the place of the steam fire engine, is the hydrant. At this point the fireman's work begins, and no part of the system is more important in determining its efficiency. The hydrant must give reliable service and unfailing operation. Its chief points are as follows:

1. *Type and Construction.*—Under this head there is to be considered design, material and workmanship, so combined as to give the maximum of reliability and efficiency.

2. *Performance.*—Comprising ease and certainty of operation.

3. *Frictional Losses.*—This item considers the least possible frictional resistance in the water passing through and out of the hydrant. The velocity in feet per second of the water leaving the hydrant openings should bear some standard relation to the theoretical discharge under the head of water employed.

4. *Drainage.*—Prompt and complete drainage, or sufficiently so to guarantee perfect protection against freezing in the severest climate or weather.

5. *Pressure.*—Hydrostatic test under pressures from 300 pounds to 600 pounds per square inch.

6. *Valves.*—The main valve to be not less than 6 inches in diameter of opening, downward against the pressure, and provided with a pilot valve which is to be opened by the first two or three turns of the wrench, thus equalizing the pressure both sides of the main valve and producing practically a non-resisting opening of the hydrant for service easily and quickly.

The average working fire pressure at such hydrants is not far from 200 pounds although 175 pounds is not infrequently used; the system is usually designed for a working pressure of 300 pounds. Lengths of hose lines are rather indefinite, and stretch according to circumstances in the field. So many combinations can be made by siamese connecting, to reduce and modify the frictional loss, depending upon

the good judgment of the fire chief, that standardization hardly comes in for practical hose work. The original New York high pressure hydrants were arranged with one 4½-inch and three 3-inch outlets, but the later hydrants are designed with four 3-inch outlets, pointing out the fact that standard 3-inch hose are evidently more practicable to carry and handle, giving greater length per weight, and also giving a frictional loss unobjectionable in the lengths of lines ordinarily used. If long lines are needed which are the exception, two or four single lengths of 3-inch hose may be joined into 4-inch hose, or if necessary into 6-inch, and so the friction reduced to a pressure which will provide a very long line or two with the minimum of reduction between hydrant and nozzles. Conditions might be possible in a long stretch, where a 6-inch line after carrying the water under good working pressure for a considerable distance, to divide into four 3-inch working lines close to the fire.

It goes without saying that the systems of high pressure fire service in operation and in course of construction are covered by the same general principles, varying to suit local conditions, and sooner or later material standardization will take place in many of the details, as is clearly outlined by the habits or practice already developed in handling such systems, and following this line we next come to,

Pumping Machinery.—No standardization has yet taken place in this field. Steam, gas and oil engines may be successfully employed as well as electrically operated centrifugal pumps. The best known plants now in service were originally installed as follows; with provisions for extensions and enlargements:

New York City

a. Manhattan Borough . . . . . normal capacity, 30,000 g.p.m.
b. Brooklyn Borough . . . . . normal capacity, 21,000 g.p.m.
c. Coney Island . . . . . normal capacity, 4,500 g.p.m.

Manhattan Borough: 2 stations, 5 units in each station, 3,000 g.p.m. normal capacity, each unit.

Brooklyn Borough: 2 stations, 4 units in one and 3 units in the other; 3,000 g.p.m. normal capacity, each unit.

Coney Island Station: 1 station, 3 units; 1,500 g.p.m. each unit.

Philadelphia

Delaware River Station: 1 station, 7 units of 1,400 g.p.m. each and 2 units of 600 g.p.m. each.

Winnipeg

One station, 6 units, 1,800 g.p.m. each unit.

Essential facts developed from service which give a fairly clear idea of this form of fire fighting may be gleaned from the following:

Units may be started as service demands.

Full pressure can be put on system in 45 to 60 seconds.

Entire station may be placed in full operation in 7 to 10 minutes.

Fifteen to twenty, 2-inch streams or the equivalent may be concentrated on any one block within the protected territory.

Twenty-one, 3 inch lines may be simultaneously used, serving twelve 2-inch and nine $1\frac{3}{4}$-inch nozzles, maintaining 80 pounds nozzle pressure.

A water tower with a 2-inch nozzle, giving a nozzle pressure of 175 pounds, and a deck pipe with a $1\frac{3}{4}$-inch nozzle, giving a nozzle pressure of 195 pounds may be quickly concentrated, and such streams will go from 50 to 75 feet above a 20 story building.

Where gas power is used it is found that:

Compressed air starting is fully competent.

Drop in air pressure from initial of 200 pounds to 125 pounds, in starting five 1400 gallon units.

Time required to replace an igniter, four minutes.

City gas supply generally adequate and effective.

Current from street service most desirable for ignition.

Battery and mechanical relay current fully competent.

Operating cost, total per 1000 gallons, 12 cents average.

Where electric power is used it is found that:

The maximum pressure may be developed in 46 seconds.

Starting current does not exceed 150 per cent of full load current.

A current of 3-phase, 6600-voltage, and 25 cycles gives safe and satisfactory service.

Induction motors provide very quick starting, besides being safe and reliable.

Where proper precautions are taken, the current is reliable.

Operating cost for power, 9.17 cents per 1000 gallons.

THE DISTRIBUTION SYSTEM

The distribution system, or the "Gridiron" as it is frequently called on account of its fancied resemblance to that utensil, has been practically standardized into four sizes of mains:

For Cast Iron Pipe

NOMINAL INSIDE DIAMETER IN INCHES	THICKNESS OF PIPE; INCHES	STRAIN PER SQUARE INCH OF METAL	SAFETY FACTOR; WITH METAL AT 20,000 POUNDS
12	1	1800	11.10
16	1¼	1920	10.40
20	1½	2000	10.00
24	1¾	1920	10.40

The material, whether of cast iron or steel is yet in controversy, both having intelligent advocates. The New York system is of cast iron, bell and spigot water pipe of the regular pattern generally, but having special bells and spigots. This pipe was made with two lead grooves in the interior of the bells and also at the outer surface of the spigots, and the lengths were cast on end, bell end down, with the spigot bead end greatly enlarged and lengthened, afterward being cut off so as to form approximately the regular bead end, and ensuring sound metal at that point.

Steel mains now being installed in Baltimore have yet to be tried out, the chief item of uncertainty and anxiety being the joints where the lengths are joined. But in due course of time the pipe which is the best for the service will take its place, the freedom from leakage and the staying qualities in the long run being important controlling factors.

In the New York system the allowance for leakage specified before construction, was during a 10-minute test, at the rate of 4 gallons per 24 hours per lineal foot of pipe joint, equal to an aggregate leakage for the entire system of about 1 per cent of the total pumping capacity. The leakage test after completion proved to be about ⅛ per cent which not only seems very satisfactory considering the immense number of joints, but will be extremely difficult to excel with any form of pipe or joint. The breakages in the New York system were only three during the first 18 months, and in castings which had withstood 650 pounds foundry test pressure; two of these breaks occurred at 150 pounds and one at 300 pounds and might possibly have been caused by an instantaneous water ram, so brief as to escape observation.

Two important factors covering distribution of hydrants are as follows:

Acres of Protected Area Served per Hydrant

	Acres
Manhattan system, per hydrant	1.14
Brooklyn system, per hydrant	1.89
Coney Island system, per hydrant	1.92
Philadelphia system, per hydrant	2.56

Lineal Feet of Gridiron Main per Hydrant

	Feet
Manhattan system, per hydrant	233
Brooklyn system, per hydrant	166
Coney Island system, per hydrant	170
Philadelphia system, per hydrant	285

There are many more details in the designing and construction of the high pressure fire protection system, impracticable to go into within the limits of a paper of this scope, and which would further lengthen a paper already rather extended, and among questions likely to arise in the minds of those interested in such matters, is that of comparative investment and usefulness. But an investment comparison between the steam fire engine system and that of direct hydrant pressure under present day conditions, would require a great deal of research into statistics and even then, the obvious difference between organized resistance to the forces of destruction, and the elements and results entering into a business proposition looking for profit, introduces a strong sense of the illogical. The steam fire engine, the chemical engine, and the high pressure system each has its legitimate field, and the border land between them is not yet clearly defined and never may be. All three will work advantageously together under some conditions. Each will be supreme in its own proper environment. It is currently reported in New York City that $500,000 is annually saved in fire insurance rates on account of the high pressure system; this capitalized at 5 per cent represents $10,000,000. The system cost in round numbers $3,500,000, which deducted from the above capitalization leaves $6,500,000 to the good according to the bookkeeping at least. Brooklyn treated the same way shows a credit of $3,500,000 net on an investment of $1,500,000.

Now, turning the same kind of bookkeeping search light upon the steam fire engine system, the following may be noted:

At the fire of January 7, 8 and 9, 1909, 40 steamers, 600 men and 12 battalion chiefs were summoned as a reserve, embracing every engine and company south of 37th Street. None of this reserve was needed, the high pressure system completely handling and subduing the threatened conflagration. The capacity of these steamers under

best conditions would have been about 20,000 g.p.m. under, not exceeding perhaps 185 pounds air chamber pressure, and 60 pounds nozzle pressure. The inevitable long lines of hose with the use of so many engines, some of them located unavoidably a considerable distance from the fire, would reduce even these figures.

The high pressure system which actually handled the fire without assistance from the steamers, delivered 35,000 g.p.m. at a pump pressure of 225 pounds a hydrant pressure of 205, and probably a nozzle pressure as high as 100 pounds or more on water towers and deck pipes, and as high as men could handle from hose lines, possibly 80 pounds.

In value these engines represent approximately $200,000, to which would be added $50,000 for hydrants, but there would be no charge for mains because the domestic service is taken from the same pipes. The difference in men required, value and maintenance of horses, capitalized, and added to fire engines and hydrants gives a total of about $6,000,000 as a sum necessary to invest at 5 per cent to keep up the fire engine system.

Just how this kind of bookkeeping will ramify and apply to various phases of the matter requires a good deal of careful consideration of each case by itself, but the general principle may be laid down, that where we find many buildings are more than five stories high, and where great values are concentrated in many buildings in thickly built up districts, even of moderate heights, it will pay to look into the merits and effectiveness of the two systems. There is no body of business men who possess ideas of higher practicability than fire underwriters. They know exactly where their risks and dangers are, and they apparently consider it better business to have very low rates where there is a minimum risk, than higher rates at a much greater risk. Dwelling houses where people are constantly about, few in number, and always "on guard" so to speak, are insured at extremely low rates of premium; while some manufacturing risks are so great that 100 per cent per annum, would be undesirable. Fire insurance companies have learned by long experience, more or less bitter at times, exactly where the danger line is located, and are good judges of building construction, value of means for preventing fires, also value of means for extinguishing fires, and they govern themselves accordingly. They are veritable thermometers regarding the hot spots, and insurance rates represent the mercury going up and down in the tube.

SYDNEY WATER SUPPLY, ITS HISTORY AND MANAGEMENT

By Charles W. Smith, M.Inst.C.E.

Sydney, the capital of New South Wales and Mother City of the Australian Commonwealth, stands on the shores of Port Jackson. The city and its suburbs, which conjointly form Greater Sydney, occupy an area of about 175 square miles, and in June, 1910, it was estimated, had within its boundaries, 668,940 inhabitants. The site of the city was selected by Captain Phillip, the first governor of the colony in 1788, his principal reasons for its choice being the commodious harbor and a stream which appeared to promise a permanent water supply. The entrance to Port Jackson lies between perpendicular cliffs of sandstone 400 to 500 feet high and only 74 chains apart. Sydney Harbor has been so frequently described by its admirers that it is unnecessary to descant on its natural beauties. Its great depth of water and natural shipping facilities doubtless give it the first place among the harbors of the world. The harbor proper has an area of 15 square miles while the estuary has a shore line of 165 miles. The main branches of the harbor run up into the land like the fingers of an outspread hand, enabling ocean steamers to lie alongside the busy streets. The land lying between these fingers attains an altitude up to about 160 feet, and this conformation doubtless provided many difficulties to the municipal and water works authorities in the early days.

The mean range of temperature of Sidney is only 19.2° Fahr. The mean summer temperature being only 71° and that of winter 54°. The highest temperature in the shade ever experienced in Sydney was in 1896, when 108.5° was registered; while the lowest was 35.9° on July 12, 1890, which gives a range of 72.6.°

The mean amount of evaporation per annum is 37.42 inches. In Australia the question of evaporation is of more than ordinary importance since much of its drier region relies so largely on storages for its water supply. In the interior of New South Wales it reaches as high as 84 inches. The mean number of days in which rain fell was 159.8. The prevailing wind is northeast.

EARLY WATER WORKS

Although the stream above referred to, which was afterwards known as the tank stream, had to serve the settlement for many years, it was evidently quite inadequate to meet the wants of the population as early even as 1789, when a severe drought was recorded. But beyond cutting three tanks out of the solid rock near the mouth of the stream, and taking measures to prevent pollution of the water nothing was done until 1827 when the Lachlan Swamps, situated about three miles out of the town, and lying amongst sandhills, were drawn upon. A tunnel 5 feet by 4 feet known as Busby's Bore, was driven through an intervening ridge, and the water conducted to a public reserve knwon as Hyde Park, whence it was distributed from a standpipe to the higher parts of the town, and by gravitation to the lower levels. This tunnel, which was $2\frac{1}{4}$ miles long, involved 255,930 cubic yards of excavation, and cost £24,000. Convict labor was principally employed, which added to the difficulties of the undertaking. The work occupied ten years, and the population in that period increased from 10,000 to 20,000. The capacity of the tunnel was from 300,000 to 400,000 gallons per day.

In 1857 the Lachlan Swamps were further utilized, and a series of dams were therein built for the storage of about 475,000,000 gallons. A pumping plant, consisting of three pumping engines of the beam type of 100 horse power each, was erected at the lower end of the swamps at Botany Bay. A 30-inch cast-iron rising main was laid to the city, where two service reservoirs were built, one at Crown Street, 139 feet above sea-level, containing 3,500,000 gallons, and another at Paddington, 214 feet above sea-level, containing 1,500,000 gallons, and pipes laid therefrom supplying water under pressure. For these works £200,000 were voted by the Legislature. A prospective population of 250,000 was thus declared to be provided for, allowing a per capita consumption of 30 gallons per day.

Sydney had to rely on these waterworks until about 1880 when the Nepean scheme was inaugurated. And it is these works and their development that the author proposes to describe in this paper.

The Nepean Scheme.—In 1867 it became obvious that the existing water supply was inadequate, as it could not be relied upon in all seasons. To insure the careful consideration of the many suggested schemes for its augmentation a Royal Commission was appointed. Its deliberations extended over two years, when it unanimously decided on what is known as the Upper Nepean scheme, which possessed

those qualities so eagerly sought for in all great projects of water supply. It had an ample catchment area of sufficient altitude; there were undoubted indications of an abundant rainfall; and the chemical analyses showed the water to be of excellent quality.

The question of high or low level service was discussed, and principally on the score of economy, the latter was finally selected. It was at first thought that it would be better to build dams on the rivers themselves, and although several suitable sites were found, it was ultimately decided not to recommend the construction of any of these for the present; the heavy floods to which all our rivers are subject would have rendered such works very expensive, and it was thought better to have one large reservoir near Sydney apart from the rivers, instead of dams of possibly smaller capacity within the catchment basin.

The works carried out and now existing followed very closely the lines laid down by the Commission.

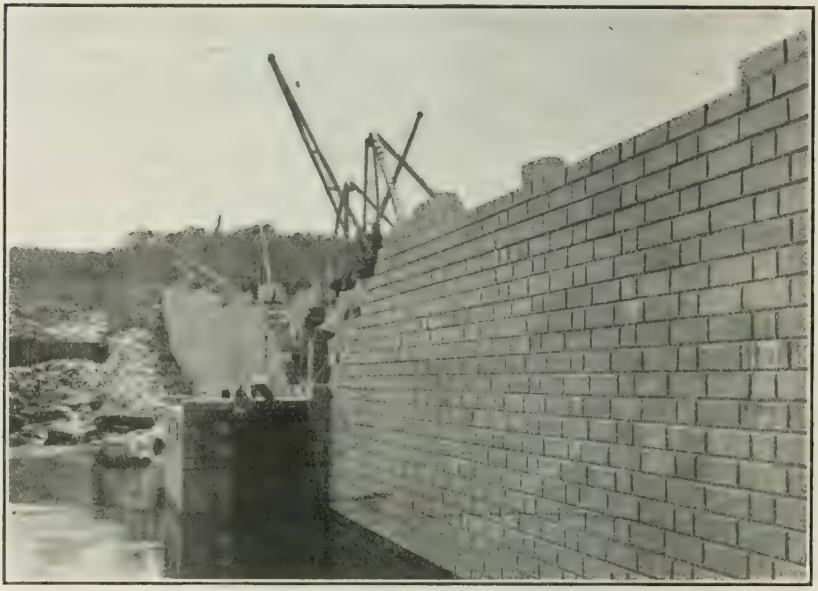
SYDNEY WATER SUPPLY 1910

Catchment Area.—The catchment of the Sydney water supply has an area of 354 square miles. It includes the watersheds of the Cataract River and its confluent creeks, embracing 82 square miles; and those of the Nepean, Cordeaux, Avon, and Bourke Rivers, amounting to 272 square miles. The Nepean, Cordeaux, and Cataract take their rise on the western slopes of the Illawarra coastal ranges, and receive the drainage of the elevated table land which extends from near Bulli on the north, to Mittagong on the south, a length of about 30 miles, having a mean width of 13 miles. Its mean elevation is about 1800 feet above sea-level. With the exception of about 40 square miles of basaltic country the whole of the basin is of sandstone formation, sparsely clothed with stunted vegetation. Near the range on the eastern side, it spreads out into numerous swamps, while along its western margin the plateau is broken by various tributaries which fall from the table land into the deep gorge through which the Nepean flows, almost from its source till it emerges in the open country near Menangle. No country could possibly be more suitable as a gathering ground for a city water supply, both as regards extent, geological formation, great elevation, proximity to the sea, and the character of its vegetation. The flood waters of the Nepean, Cordeaux, Avon, etc., are unretarded, and when exceeding 90,000,000 gallons per day (that being the carrying capacity of the

diversion tunnel) pass down to the sea. The flood waters of the Cataract River and Creek are in part controlled, being held back by the Cataract dam which will be described later on.

Within the catchment area the water board's power is limited to the insistence of sanitary conditions among the settlers. The felling of timber on crown land has been stopped, but this is not the case on private property, where timber getting is uncontrolled.

Storages in Catchment Area.—The long dry period of 1901–03 proved the necessity for again augmenting the supply. Prospect,

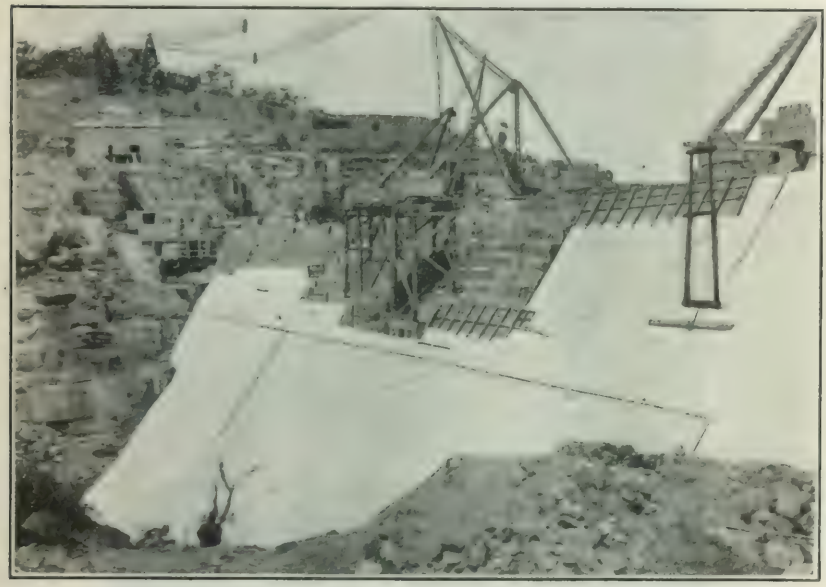


Cataract Dam When Under Construction

the only storage reservoir, had its contents reduced below gravitation level. At this time another Royal Commission was appointed to make full enquiry into the Sydney water supply, and inter alia, it recommended a storage on the Cataract River within the catchment area.

Experts, to whom the question was remitted, decided that the dam should be built to store 21,411,000,000 gallons or thereabouts, that is to say that it be built so that its full supply level, the level of the sill of by-wash or waste weir, should be 150 feet above the natural level of the river bed at the site. This conclusion was

arrived at after a careful digest of the available river gaugings and rainfall records. From these it appeared safe to conclude that the Cataract catchment, above site of dam, estimated at 50 square miles, might discharge 32,000,000,000 gallons in a year of maximum rainfall (91 inches); 14,750,000,000 in a year of mean rainfall (53 inches); and 4,000,000,000 gallons in a year of minimum fall (27 inches). Yet in 1903 had Cataract dam then existed of the capacity decided upon it would have been emptied as the result of the terrible drought, and Prospect reservoir would also have been down

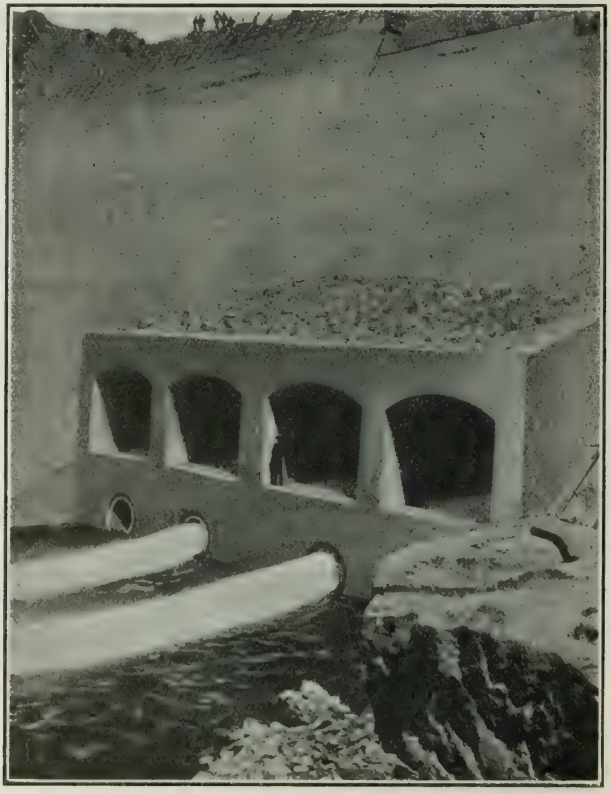


Cataract Dam When Under Construction

to gravitation level. But the 1901–1903 drought was not comparable to that of the 1880–1886. And these facts afforded the strongest reason for providing so large a storage capacity.

The Cataract dam is built just below the confluence of the Cataract River and Creek in a deep gorge of Hawkesbury sandstone. Its leading dimensions are: Length of wall, 811 feet; height above river bed, 157 feet; depth below river bed, 35 feet; maximum total height from base to top, 192 feet; top width, 16.5 feet; bottom width, 158 feet; maximum depth of water stored, 150 feet; length of by-wash, 715 feet. The dam is built of Cyclopean masonry com-

posed of large sandstone blocks weighing from 2 to $4\frac{1}{2}$ tons, bedded in cement mortar, and the vertical joints filled with basalt, or vitrified sandstone-concrete. The upstream face consists of basalt concrete moulded blocks set in cement mortar. The downstream face is of basalt concrete 6 feet thick in the lower, and 3 feet thick in the upper levels. In its construction 215,000 cubic yards of



Cataract Dam Under Construction

excavation were involved, 19,000 tons of cement were used and 319 tons of iron work fixed. There were altogether 146,242 cubic yards of masonry and concrete. There are four lines of 48-inch pipes through the dam, two of which were retained as a permanent outlet for supply. The total cost of the work was £329,136 12*s*. 7*d*. The time occupied in its building was nearly five years.

Diversion Works.—By aid of a weir, built across the Nepean River at Pheasants Nest, 63¼ miles from Sydney, a certain portion of the combined flow of that river and the Cordeaux is diverted, by way of a tunnel 4½ miles long, into the Cataract River across which a similar structure has been built to turn it into another tunnel, about 1¾ miles in length. This tunnel leads to Appin, and is carried along the ridge dividing the Nepean and George's Rivers watersheds by a succession of channels, tunnels, and pipe aqueducts to Prospect reservoir. I will briefly describe these works of conveyance from the catchment to Prospect, without going into such detail as would be required for a specification.

The Nepean weir which is about 10 feet high is built of concrete, and has a crest level of 439.5 feet above sea-level. The Nepean tunnel which connects the Nepean and Cordeaux with the Cataract River is 9 feet, 6 inches wide and carries 7 feet of water, the grade is 2 feet 6 inches per mile. Its capacity is about 90,000,000 gallons per day.

The diversion weir at Broughton Pass, Cataract River, is built of concrete reinforced with railroad iron, has a crest level of 426 feet and diverts the whole of the water taken for Sydney into the Cataract tunnel, which is 10 feet 6 inches wide, and with a depth of 8 feet of water and a grade of 3.5 feet per mile, discharges about 150,000,000 gallons per day. The tunnels are unlined being principally cut through Hawkesbury sandstone with an occasional section of shale, which will, at an early date, be lined with concrete. The roof is semicircular with the side walls vertical and the invert slightly dished. The widths given are the diameters of the circle. It was not anticipated by the designers that the tunnels would run full bore.

Consistently with the preservation of easy curves, the line of channel was kept as near as possible to the surface level of the ground. Provision is made throughout the entire length of aqueduct to intercept and carry off all the surface drainage of the land through which the channel passes. There are numerous wrought-iron pipe inverted siphons of 7-foot, 6-inch and 8-foot diameter, of lengths ranging from 150 feet to 655 feet across creeks and depressions. All but two of the tunnels are brick-lined. At stated intervals along the line of channel drop-bars are fixed to facilitate cleaning and repairs. Offtakes, to supply the small neighboring towns of Campbelltown, Camden, and Liverpool are provided; services are permitted to some of the larger holdings. Above the Race into Prospect reservoir a measuring weir is fixed, the lip of the plate being 243.15 feet above the sea-level.

Prospect Reservoir.—This reservoir is formed by an earthen embankment built across the valley of Prospect Creek. The length of the dam is 7300 feet, its maximum height 85½ feet. The slope on the up-stream side is 3 to 1, that on the down stream side 2½ to 1, with two berms 15 feet wide. The width of the dam at the top is 30 feet. The puddle wall, which is 5 feet below the crest of bank, is 9 feet 3 inches wide at top, and has a batter, on each side, of 1 in 8 down to the original ground level, when it narrows in at the same batter to sufficient depths to ensure water-tightness. Ballasting as a protection to the inner face is carried up from a stone dyke at the toe of the slope to 180 feet R.L., and from thence upwards diorite pitching is laid The submerged area, at full supply level is 1266.3 acres; its total contents 11,029,180,000 gallons. The outlet works include a brick and stone tower, within the reservoir, with a brick lined tunnel carried round the end of dam through solid ground to the valve chamber at the head of lower channel, or canal, which conducts water to pipe head. Within the tunnel are laid two 48-inch cast-iron pipes controlled by valves in tower and valve chamber, and discharging through a 48-inch Venturi meter, which is fixed near valve chamber, and measures the volume passing down to Sydney.

Lower Channel or Canal.—Water coming from Prospect after passing through the Venturi meter, discharges into the receiving basin, at the head of the channel or canal, which conducts the water to pipe head, from whence it is distributed to the various centres. The canal is about 4¾ miles long. Its present capacity is 50,000,000 gallons per day. This conduit is now being enlarged, increasing its carrying capacity to 87,000,000 gallons per day. At about three-quarter mile from Prospect the creeping nature of the ground (decomposed diorite and clays) through which the canal passes, necessitated the building in concrete of a covered way 950 feet long. The brick aqueduct at two miles from Prospect, 740 feet long, was unsuitable for economic enlargement, so to meet the increased requirements, it has been supplemented by an inverted concrete siphon 1000 feet long, 10 feet 8 inches inside diameter, 6 inches thick, reinforced with steel bars.

At pipe head basin, at the end of the channel, three trunk mains take off: First, a 32-inch steel locking-bar pipe 9.17 miles long leads to Ryde where is established the pumping station which supplies the whole of the reticulated area north of Port Jackson. The two other pipes 72 inches in diameter, and five miles long each, are

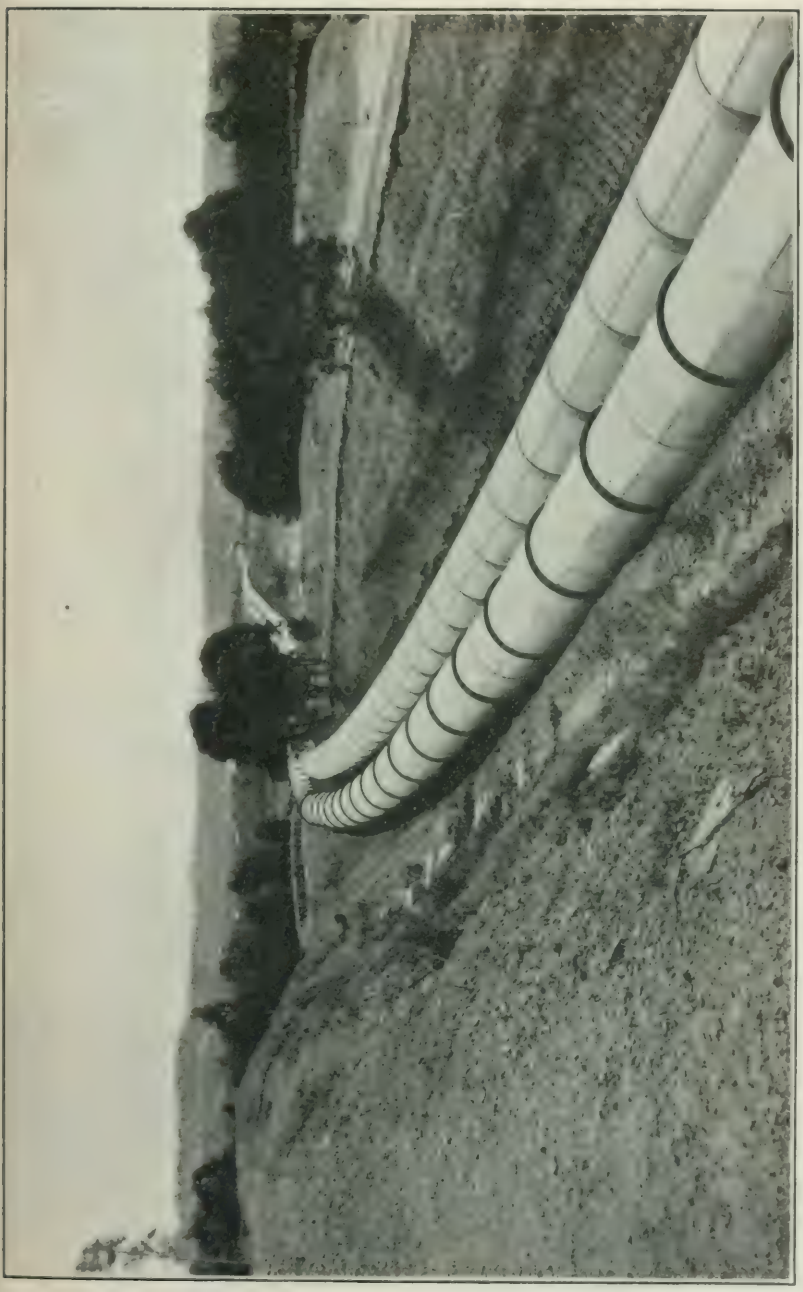
Valve House and Basin at Head of Lower Canal

laid to Potts Hill Balance Reservoir, supplying all districts south of Port Jackson.

Pipe Head to South Sydney.—The 6-foot pipes are controlled by penstocks fixed at the lower end of pipe head basin. The first of these pipes is of wrought iron of $\frac{3}{8}$, $\frac{7}{16}$, and $\frac{1}{2}$-inch thickness, riveted with $\frac{3}{4}$-inch rivets in four pieces 12 feet long, each length being connected with a steel collar, run with a lead joint. This main runs direct to Potts Hill screening tank, with a 4-foot branch into Potts Hill reservoir. The second main is of mild steel $\frac{1}{4}$-inch and $\frac{5}{16}$-inch thick, riveted with $\frac{1}{2}$-inch and $\frac{5}{8}$-inch rivets, with angle-iron flanged joints. In other respects it follows the original main, all branches being repeated. This main discharges direct into the reservoir, but is connected with the screen tank by a cast-iron by-pass of 6-foot and 4-foot diameter, laid along the floor of reservoir to the two valve towers, with a 24-inch branch, off the 6-foot section, opening directly into the reservoir. The difference of levels between pipe head basin and full supply level at Potts Hill is 3 feet, and the levels of the pipe lines are such that water can feed back from Potts Hill up to a point 570 feet from pipe head. A by-pass therefore connects two 6-foot pipes with the Ryde main, used only in cases of emergency when the lower canal is shut for repairs. There is one branch 18-inch diameter taken off these mains to supply Granville.

All water passing down to Sydney, drawn either direct from pipe head or from the balance reservoir, must pass through the Potts Hill screening tank. This is a circular tank 52 feet internal diameter and 25 feet deep, having a top water level of 175 feet. The tank is fitted with 32 movable screens covered with 29 B.W.G. copper wire gauze, having a mesh of 30 by 24 equal 720 to the square inch. When the screens are being cleaned it is arranged that the orifice which they fill can be closed by the insertion of a dummy. From this screening tank the water proceeds to the city. The tank is fed either by No. 1 6-foot pipe, direct from the balance reservoir; or the duplicate main by way of the by-pass laid within the reservoir through the valve towers.

Potts Hill Reservoir—This tank has a capacity of 100,000,000 gallons. Its dimensions at top water level (175 R.L.) are as follows: Length, 1194 feet; width, 894 feet; available depth of water, 15 feet 6 inches; area, 24½ acres. The reservoir is built partly in excavation and partly in bank, the floor is laid in hydraulic lime concrete and the sides, which have a 1 to 1 slope, are pitched with dry coursed rubble masonry. It was originally designed to tide the



SIX-FOOT TRUNK MAIN, LOOKING TOWARDS PIPE HEAD

city over any interruption of supply from Prospect, and to prevent fluctuation of pressure.

Trunk Mains to the City.—The trunk mains from Potts' Hill consist of a 48-inch cast-iron pipe laid to Petersham, with a 48-inch branch into Petersham reservoir, and thence 42 inches to Crown Street reservoir, Sydney, with numerous branches taken therefrom to supply low level or gravitation zones both en route and within the city. A second 48-inch wrought-iron main $\frac{5}{16}$-inch thick, riveted with $\frac{11}{16}$ inch rivets is laid to Lewisham, and then cast iron of same diameter to Crown Street direct. It is not tapped en route, being especially designed to supply the pumps at Crown Street. It has a discharging capacity of about 15,000,000 gallons per day. In length it is a little over 12 miles. A third cast-iron main, laid originally to supply Ryde Pumping Station but now used as a gravitation main, is of 30-inch, 24-inch and 20-inch diameters, supplying the low levels of Concord, Leichardt and Drummoyne.

Trunk Main for North Sydney Supply.—A trunk main, partly of 32-inch steel $\frac{3}{8}$-inch thick riveted with $\frac{3}{4}$-inch rivets, and partly of 32-inch locking-bar steel pipes $\frac{1}{4}$-inch, $\frac{5}{16}$-inch and $\frac{3}{8}$-inch thick, extends from pipe head to Ryde Pumping Station suction tank, which contains 2,000,000 gallons.

Gravitation or Low Level Zones.—Of the daily consumption 40 per cent is delivered by gravitation. The zones supplied are all south of Port Jackson. The reservoirs upon which this area is dependent, are those at Potts' Hill, Petersham and Crown Street.

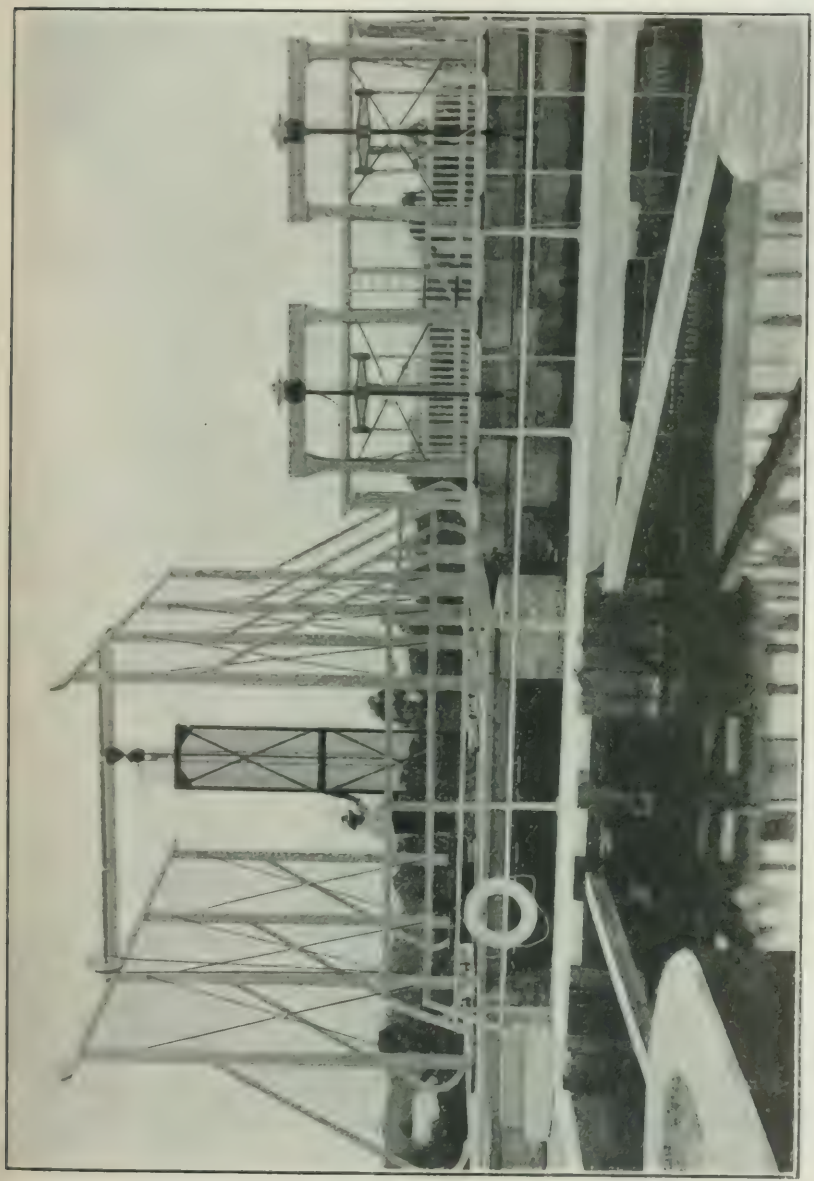
High Level Zones—The topographical configuration of Sydney and suburbs is such that very many tanks or reservoirs are necessary to insure a satisfactory service. Within the various zones also are isolated peaks requiring special mains with extra pressure.

There are nineteen zones provided with separate service tanks into which water is lifted from four pumping stations.

PUMPING STATIONS

Crown Street.—This is Sydney's principal pumping station. Here are installed four sets of pumps. Two sets are horizontal compound condensing engines of the Worthington duplex direct-acting type. The steam ends of each of these sets are the same, being 22-inch and 43-inch diameter and 48-inch stroke.

The No. 3 set of engines are duplex and of the horizontal compound condensing rotative direct-acting type, of local manufacture, and of



SCREENING CHAMBER AND PENSTOCKS, AT PIPE HEAD

146 I.H.P. They are capable of lifting 100,000 gallons per hour to Waverley reservoir. These pumps are now only used as a standby.

Steam is generated at this station by four Babcock and Wilcox water tube boilers of 142 H.P. each, with chain grate mechanical stokers.

The No. 4 set is electrically driven. It consists of a 700 H.P. 5000 volts 3-phase motor placed between and directly coupled to two high lift centrifugal pumps. It is rated at 3500 gallons per minute when running at 720 revolutions against a static head of 155 feet. These pumps are worked either in series or in parallel.

A small pumping plant which may be considered as supplemental to that at Crown Street, has been erected near Waverley reservoir. It consists of two 4-inch centrifugal pumps driven by electric motors, each set, at 850 revolutions per minute, being capable of lifting 325 gallons per minute 30 feet high, to the small adjacent tank.

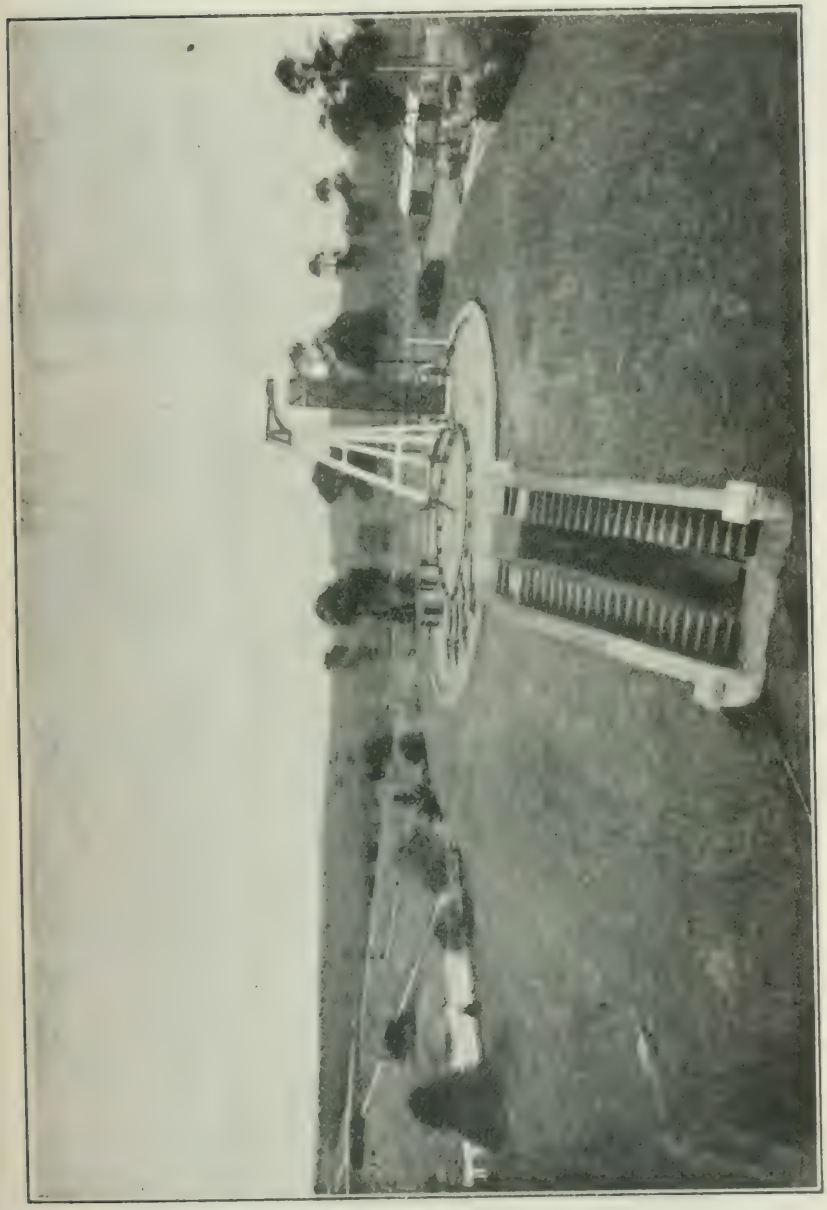
Carlton Pumping Station.—The small pumping plant here consists of two sets of Worthington compound high duty pumping engines, each capable of lifting 30,000 gallons per hour, to Penshurst tank whose top water level is 270 feet R.L., through 15,180 feet of 12-inch main. A lift of 182 feet is involved. Steam is generated by two Babcock and Wilcox water-tube boilers.

Ryde Pumping Station, North Sydney Supply.—The pumping plant at Ryde consists of two pairs of Watt engines of the vertical compound surface condensing rotative type.

Tests on these pumps were as follows:

Coal consumption per hour in hundredweights	8.40
Total water in gallons evaporated during test	6930.00
Pounds of water evaporated per hour	6930.00
Pounds of steam per hour from and at 212° F. to 117 pounds absolute	7359.00
Pounds of steam per pump horse power per hour	29.74
Pounds of water evaporated per pound of coal from and at 212° F	8.76
Average gallons pumped per minute	1125.36
Average pump horse power	233.25
Average head in feet on pumps including friction	684.00
Duty in million foot-lbs. per cwt. of coal consumed	54.98
Duty in million foot-lbs. per 1000 lbs. of steam	66.64
Average revolutions per minute	3300
Mean pressure on boiler 1021 pounds, on Turbo	46 pounds
Vacuum	29 inches

The Ryde Station is well equipped. The boilers are fitted with mechanical stokers and superheaters. A coal conveying and ash



Screening Tank, Potts Hill

handling plant is established, and coal bins, built of reinforced concrete, holding 1000 tons, are connected, by conveyor, with railroad siding and the hoppers in boiler house. The coal and feed water are both measured.

It may here be mentioned that Hermitage tank site was especially selected for its commanding position, to supply not only a considerable district on the north shore but also a large section of the western suburbs south of Port Jackson and the Parramatta River. A 32-inch locking-bar steel pipe $\frac{1}{4}$-inch, $\frac{5}{16}$-inch and $\frac{3}{8}$-inch thick has therefore been laid, crossing the Parramatta River by the Ryde railway bridge, and extending therefrom as far as Canterbury. From Strathfield the main is continued in cast-iron pipes from 24 to 20-inch diameter. Ultimately there will be three tanks at Hermitage of 1,500,000 gallons each.

Service Reservoirs.—Subjoined is a descriptive list of the service reservoirs built within the Sydney and suburban reticulated area. Only a few of these require any special mention. Large open steel tanks which are somewhat uncommon, have been extensively adopted in the suburbs of Sydney. They are cylindrical in form, and rest on a concrete bottom, the floor being about ground level. In the concrete are imbedded iron shoes upon which rests a cast-iron base-plate. In the groove of this plate stands the shell of tank built of plates from 1-inch to $\frac{5}{16}$-inch thick, butted, with cover plates. Water tightness is secured by the introduction of a sheet lead joint between the concrete floor and the shell. These tanks are only erected in distant suburbs where population is sparse and the air comparatively free from impurities. Some have been in existence for over twenty years and their efficiency is unimpaired.

Open concrete tanks have also been built in outlying districts, they are circular in form, and are half in and half out of the ground.

Centennial Park reservoir is imposing from an architectural standpoint, and occupies a prominent position in our largest public park. It is built of brick and concrete, roofed in with groined arches of coke concrete. The roof surface is laid down in grass and made available to tennis clubs. The reservoir is divided into two sections. Around the valve house is built an ornamental kiosk, and the whole area is fenced in by handsome cast-iron railings.

Recently, a reinforced concrete tank has been built on the sandhills at Randwick. It stands half in and half out of the ground.

To supply the small towns of Campbelltown, Camden, Liverpool, and Smithfield, open circular tanks have been built close to the

main aqueduct or channel, from which they are filled, and mains laid therefrom to the towns they command. The reservoirs of Richmond and Wollongong are given in the subjoined list, but the water works of these towns have not been transferred to the board. That body merely manages them on behalf of the government.

List of Service Reservoirs or Tanks

NAME	DESCRIPTION	TOP WATER LEVEL (ABOVE SEA)	DEPTH IN FEET	CONTENTS IN MILLIONS OF GALLONS	DIAMETER OF INLET PIPES IN INCHES	DIAMETER OF OUTLET PIPES IN INCHES
South Sydney						
Ashfield	Open wrought iron shell, on brick substructure	223.0	16	0.10	9	9
Petersham	Brick arched roof	166.0	27	2.15	48	1-42, 1-20
Crown Street	Brick and concrete roof	141.0	15.5	3.25	2-42	2-20,1-24,1-42
Paddington	Brick and concrete roof	214.0	16.5	2.00	2-24	2-24, 2-20
Centennial Park	Brick and grouted coke concrete roof	245.0	20	18.50	42	42
Woollahra	Brick walls and roof	282.0	18	1.00	20	1-20, 1-15
Randwick	Reinforced concrete	275.0	32	1.50	15	10
Waverley	Brick walls and roof	360.0	20	1.08	18	1-15, 1-24
Waverley (high level)	Open wrought iron on iron columns	380.0	5	0.04	12	6
Vaucluse	Open concrete	312.0	18	1.00	12	12
North Sydney						
Ryde Suction	Open brick work	97.0	22	2.00	1-30, 1-32	1-36
Ryde Village	Open steel	234.0	22	1.00	24	18
Hermitage	Open steel	302.7	40	1.50	20	1-32, 1-20
Chatswood	1. Open steel	370.0	32.5	1.50	24	1-20, 1-18
Chatswood	2. Open steel	370.0	32.5	1.50	24	1-20, 1-18
Pymble	Concrete walls and roof	567.0	20	0.50	15	15
Wahroonga	Open steel	706.0	26	1.00	15	15
Wahroonga (high level)	Open wrought iron on timber trestles	717.0	5	0.04	9	9
Beecroft	Open steel	648.0	32.5	1.00	10	1-10, 1-8
Mosman (Brady Street)	Concrete roofed in with tiles	302.0	20.5	1.92	15	15
Mosman (Cross Street)	Open steel on brick piers	354.0	17.3	0.67	12	12
Manly	Open concrete	227.8	30.0	.94	10	10

List of Service Reservoirs or Tanks—Continued

NAME	DESCRIPTION	TOP WATER LEVEL (ABOVE SEA)	DEPTH IN FEET	CONTENTS IN MILLIONS OF GALLONS	DIAMETER OF INLET PIPES IN INCHES	DIAMETER OF OUTLET PIPES IN INCHES
		Country Districts				
Campbelltown	Open concrete	380.6	16	0.50	12	12
Camden	Open concrete	370.9	16	0.10	12	8
Liverpool, Dam	Earthen Dam	245.0	10	4.00	9	9
Liverpool	Monier concrete	207.0	15	0.25	12	12
Smithfield	Open concrete	175.0	17	0.10	12	6
Wollongong	Concrete walls and roof	243.0	17	0 40	6	8
Richmond	Open brick work	206.0	13	0.22	6	6

DISTRIBUTION OF WATER

Mains, Arterial and Distributory.—The length of mains under the board's control is 1598 miles, and is made up as follows: 10 miles of 72-inch diameter; 20 miles of 48-inch; 5 miles of 42-inch; 5 miles of 36-inch; 15 miles of 32-inch; 5 miles of 30-inch; 19 miles of 24-inch; 26 miles of 20-inch; 23 miles of 18-inch; 5 miles of 15½-inch (locking-bar); 47 miles of 15-inch; 58 miles of 12-inch; 38 miles of 10-inch; 56 miles of 9-inch; 30 miles of 8-inch; 334 miles of 6-inch; 3 miles of 5-inch; 868 miles of 4-inch; and 34 miles of 3-inch diameter. It will be noticed that 4-inch pipes are mostly in use, then come the 6-inch. No mains are now laid under 4-inch in any street. Generally speaking the pipes are on the side of thoroughfares, about 20 feet from the street, or road alignment. In the city and densely populated districts a main is laid along each side-walk. The pipes have from 2-foot 3-inch to 3-foot cover. (no frost here penetrates the ground to any depth). Branch mains are all controlled by a stop valve fixed on the street line. A general map showing the trunk and secondary mains accompanies this paper.

Types of Pipes and Fittings.—The cast-iron socket and spigot pipes are of the usual type, and are uniform throughout. The inside of socket has a groove near the face to key the lead, and the spigot end is provided with a bead. Joints are made with yarn and lead run hot and caulked. The special pipes for branches and curves are short both in length and radius. The pipes are coated

with what is known as Dr. Angus Smith's composition. The sluice- and stop-valves are of the ordinary double-faced flanged type, with socket and spigot attachments. Hydrants are either screw down, ball, or spring valve. The screw down hydrant is only used within the city, and fixed invariably on the footpath with which the surface box, protecting it, is flush. Ball-hydrants which were formerly universally used outside the city, are now only to be found on summits, where they can act as air escapes in recharging mains. The dangers attendant on the mode of using these ball-hydrants in suburban streets constituted a standing menace to the public health, the more so because tapping under pressure was not then practiced, and the flushing out of filth from mains from which water had been allowed to escape was never quite satisfactory. It was determined to replace the ball by a gun metal hemispherical spring valve, the spindle of which is made to work in a guide which seats into the cup that formerly held the ball. Some 15,000 have now been fixed, and after several years' experience proved to be satisfactory to those most concerned, viz., water works and fire brigade employes. So excellent is this spring valve held to be that the standard hydrant is now provided with this device modified as to its fitment in the body of the hydrant. The metal valve, with the convex face upwards, seats on a three-ply insertion washer.

Steel Pipes.—Steel pipes from 72-inch down to 8-inch diameter have been laid. The smaller sizes have not been a success. There are on the works four types in use: Riveted, with flanged joints; riveted, with collar or sleeve joints, run solid with lead; riveted, with socket and spigot, having joints run with lead and yarn; and the locking-bar, with sleeve joint, run solid with lead. The pipes have been dipped with various coatings. The 30½-inch rising main to Ryde was coated with 75 per cent Trinidad asphalt and 25 per cent of Maltha; the 8-inch Beecroft main with 50 per cent Trinidad asphalt and 50 per cent of coal tar distilled until free of naphtha. A perfect coating has not yet been found. The steel pipes are very readily attacked by the salt and acid in the soil, especially in the shale country. Where bends and branches are required in steel mains, cast-iron specials are introduced. Manholes are provided in all the large sized pipes, cast or steel, at stated intervals to facilitate jointing, inspection and cleaning.

Wooden Pipes.—As an experiment there have been recently laid 4½ miles of 8-inch Oregon stave pipes, bound with steel wire and

coated with Trinidad asphaltum and tar. The joints are made by driving the spigot into the socket. This pipe replaced a steel one of the same diameter which had perished after a very brief life.

Service Pipes.—Service pipes from the main to the tap, are the property of the householder, and are laid and maintained at his cost. It is required that mains be tapped on the top, and that the ferrule there fixed be of the high pressure, loose-valve screw-down type. Invariably the service piping is of galvanized iron. It is also obligatory, to fix a path- or boundary-cock on each service, and that all fittings within and without the owner's boundary be of an approved type tested and stamped with the board's mark. Where groups of closely built houses obtain, owned by the same proprietary, a large service or submain is permitted, but a governing stop-cock is insisted upon at the boundary, with a stop-cock on each branch therefrom. Fire services, of a diameter to be agreed upon, are permitted to large properties and a system of hydrants allowed within the boundaries, such hydrants being sealed by the board, and only broken in case of fire, or for wet practice, after which they are again sealed.

Quality of Water.—So far, no artificial purification of the water supplied by these works has been attempted, neither is it deemed necessary. The catchment area is constantly patrolled by rangers, and the regulations, which have been framed in the public interest, against pollution of the streams, are stringently enforced.

The board has in its employ a medical officer and bacteriologist, whose investigations as well as those of the government analyst, show the water to be perfectly fit for dietetic purposes. The result of screening the water through the copper gauze at pipe head and Potts' Hill is very marked. Free ammonia is reduced by 82 per cent; albuminoid ammonia by 61½ per cent; oxygen absorbed by 31 per cent; and iron by 81 per cent. The average results of monthly chemical analyses of water from the storage reservoirs; main aqueducts; before, and after screening at Potts' Hill; and from the service tanks within the reticulated area are given below:

Average Monthly Analyses—Parts per 100,000

SOURCE	COLOR	CHLORINE	NITROGEN				OXYGEN ABSORBED IN FOUR HOURS
			Free Ammonia	Albuminoid Ammonia	Nitrites	Nitrates	
Cataract reservoir	17	2 86	0.0041	0 0186	Nil	0 0088	0 2020
Outlet of Nepean tunnel	32	2 26	0 0010	0 0119	Nil	0.0098	0.1185
Canal at Kenny Hill	48	3 09	0.0013	0 0188	Nil	0 0100	0 1796
Canal above Prospect	44	2 69	0 0023	0 0157	Nil	0 0085	0 2013
Outlet from Prospect	18	3 00	0 0009	0.0156	Nil	0.0023	0 1374
Pipe head basin	18	3 00	0 0018	0.0206	Nil	0.0028	0 1606
Potts' Hill above screens	18	3 00	0 0038	0 0417	Nil	0.0045	0.1910
Potts' Hill screened water	19	3 00	0 0007	0.0164	Nil	0 0027	0.1318
Petersham service reservoir	18	2 99	0.0016	0 0204	Nil	0.0037	0.1526
Crown Street service reservoir	17	2 99	0.0003	0.0142	Nil	0.0035	0.1248
Centennial Park service reservoir	19	2.98	0 0012	0.0174	Nil	0.0036	0 1436
Wahroonga open steel tank.	17	2.98	0.0011	0.0138	Nil	0 0046	0.1156

The bacterial examinations made from time to time both by the board's officer and several other eminent bacteriologists, all indicate that the water may be safely used for any purpose.

MANAGEMENT AND MAINTENANCE

Constitution of Governing Body.—Prior to the constitution of the Metropolitan Board of Water Supply and Sewerage, by Act of Parliament in 1880, the water supply was controlled by the Municipal Corporation of Sydney. The first board under authority of this Act was elected March 22, 1888. It is composed of seven members, three of whom, including the president, are appointed by the governor in council, two are elected by the city municipal council, and two by the mayors and aldermen of the several boroughs and municipal districts benefited by the works, and situated within the county of Cumberland.

Subdivision of Staff.—The staff is divided into two departments, administrative and engineering.

Under the head of administration are included the correspondence branch; the accountant; the assessor and receiver; the comptroller of stores; the medical officer and bacteriologist.

The engineering department is under the engineer-in-chief, who is responsible for all work carried out, either in the water or sewerage branch.

ADMINISTRATIVE DEPARTMENT

The Correspondence Branch, which is immediately under the direction of the secretary (who is the official head of the administrative department), deals with all correspondence with the public, registers all letters, and records the deliberations and rulings of the board.

The Accountant's Branch, keeps all accounts, and records all expenditures in construction, equipment, and maintenance; and prepares balance sheets and comparative statements for each year's transactions. Authorities for any expenditure, either under contract or day labor, and chargeable either to loan or maintenance, are accompanied by a numbered debit-order, and all charges against this order are so recorded in the accountant's books. From him a statement of expenditure on each individual work, can at all times be obtained. All accounts are examined and certified to by the board's auditor before being sent on to the treasury for payment.

The Assessor and Receiver's Branch.—The assessor who is also the receiver of revenue keeps all rate ledgers, values properties when the municipal assessment is not available, furnishes estimates of revenue likely to accrue from properties to which it is proposed to lay main extensions, keeps a roll of all properties and assessments, issues all rate notices, and deals with the work of levying and recovering rates, reads all meters, and adjudicates on all matters of special fees and enquires into the status of applicants for main extensions who are willing to guarantee any deficiency in the revenue to meet interest on the outlay.

Comptroller of Stores—This officer is also librarian at the head office. He controls the purchase of all goods required for the board's use, either in or out of contract, and is responsible for the safe custody of all stocks held. Material taken out of ground is dealt with by him, and, if fit for use, is reissued after being fettled and put in repair. He also controls the sale of surplus stores and is responsible for the upkeep of depots and reservoir reserves.

Medical Officer and Bacteriologist.—This officer directs the patrol of the rangers within the catchment area, for the sanitary conditions of which he is responsible; makes constant and periodical chemical and biological examination of water, from the catchment area to the house tap; controls all laboratory work, examines employes for sick leave, and candidates wishing to enter the board's service. He lectures on, and gives personal instruction in, ambulance and first aid work.

Engineering Department—Under the engineer-in-chief are the two superintending engineers, who are the chief executive officers of each branch, water and sewerage. Under them are district engineers who immediately supervise work in their respective district. The drawing office and the survey office are common to both branches.

The Pumping Staff, comprises a chief mechanical engineer, assistant engineers (all certificated), engine drivers for the smaller stations, and valve attendants. Pumping at Crown Street and Ryde is continuous in three watches.

Superintendent of Water Service.—This officer supervises all main laying (under contract, without the city; and by day labor within the city limits) controls turncocks of each district and waste water inspectors. He reports to the superintending engineer on all bursts and deficient supply, keeps all reservoirs internally clean, cleans water mains, and maintains all surface works; shuts off private services if leaking, and (under direction) in cases where rates have not been paid.

Inspector of Plumbing.—This officer assisted by a staff of inspectors (all of whom are licensed plumbers, and good tradesmen), supervises all work done by licensed plumbers, issues all permits for service extensions and main tapping. Reports on cases where complicated services require attention or alteration, and assists in the examination of candidates for diplomas in plumbing work at the Technical College. He reports on all new service fittings submitted for approval by the inventors or makers.

Mechanical Shops.—These shops are situated at Crown Street. A large staff is employed in connection with the maintenance and upkeep of meters, the manufacture of clock-work and indicators, in connection with reservoir record, gauges, and Venturi meters. The examination and testing of all fittings used, and the stamping those that fulfill the specified requirements. The shops are well equipped with lathes, and other machinery, and are capable of doing any works of repair that may be needed.

Electrical Branch.—This branch undertakes all work in connection with electric pumping stations, electric lighting, telephonic service, electrical indicators, and the overhaul of motor-cars and wagons.

Capital Account.—At the time of issue of the last annual report the capital debt of the water branch of the Metropolitan Board of Water Supply and Sewerage stood at £5,846,303. The revenue was £267,519 and the working expenses £80,281, or 30 per cent of the

Table Showing Water Pumped, Consumption of Coal, Cost of Pumping, Duties of Engines, etc.

STATION	WATER PUMPED	COAL CONSUMED INCLUDING BANKING, ETC	DUTIES OF ENGINES AFTER COAL USED FOR BANKING, ETC., HAS BEEN DEDUCTED	PUMPING EXPENSES	COST OF LIFTING 1,000,000 GALS. OF WATER 100 FT. HIGH	COST OF LIFTING 1,000 GALS. OF WATER 100 FT. HIGH	COAL CONSUMED IN LIFTING 1,000,000 GALS. 100 FT. HIGH.	GALLONS LIFTED 100 FT. HIGH PER LB. OF COAL USED EXCLUSIVE OF BANKING	TYPE OF ENGINES AND BOILERS
	Gallons	*Tons cwt. qr. lb.*	*Foot pounds.*	£ *s. d.*	£ *s. d.*	*d.*	*Tons.*	*Gallons.*	
Crown Street to Centennial Park	3,520,711,000	2,928 3 0 24	74,684,443	4,840 1 6	1 1 4$\frac{1}{5}$	0.256	0.68	666	No. 1 horizontal compound Worthington. No. 2 horizontal compound Worthington. No. 3 compound (Mort's Dock Co.) All jet condensing. Four (4) Babcock and Wilcox boilers, with mechanical stokers.
Crown Street to Woollahra	27,659,850	28 11 1 10	80,365,727				0.62	717	
Crown Street to Waverley	65,411,730	123 10 0 14	77,854,556				0.64	695	
Crown Street to Woollahra	193,279,000			5,022 12 9	2 15 3$\frac{1}{5}$	0.663			Mather and Platt's and Gwynne's high-duty centrifugal pumps, electrically driven.
Crown Street to Waverley	441,456,100								
Ryde to Ryde Hill	4,633,500	8 12 0 0	44,988,052	4,300 2 10	1 10 3$\frac{1}{10}$	0.363	1.11	401	Two (2) vertical compound surface condensing engines (by J. Watt & Co.) Five (5) sterling boilers with mechanical stokers Green's economiser, etc.
Ryde to Chatswood	807,757,190	2,906 5 0 0	43,080,383				1.16	385	

Ryde to Ryde Hill (Turbo)....	156,768,000	705 6 0 0	17,114,895	2,652 12 6	1 7 7 $\frac{9}{16}$	0.331	2.92	152	Parson's turbo-centrifugal pump, No. 2. Boilers as above.
Ryde to Pymble (Turbo).....	87,618,750	467 6 0 0	52,500,000				0.95	468	Parson's turbo-centrifugal pump, No. 1. Boilers as above.
Ryde to Wahroonga (Turbo)...	169,877,369	1,134 19 0 9	52,385,553				0.95	467	Parson's turbo-centrifugal pump, No. 1. Boilers as above.
Carlton to Penshurst.....	189,435,376	660 5 2 0	37,792,593	1,239 16 2	2 19 6	0.714	1 58	338	Two (2) compound Worthington condensing engines. Colonial tubular boiler. Babcock and Wilcox boiler.
Chatswood to Wahroonga.....	435,200	2 9 0 0	44,635,897	35 18 0	20 12 5$\frac{1}{2}$	4.949	1 38	398	Blake and Knowles' high-duty pumps. Colonial tubular boilers.
North Richmond to Richmond.	26,049,000	108 17 3 12	30,047,581	322 16 4	6 3 11	1.487	2.09	263	Tangye's 2-throw deep-well pumps. Colonial tubular boilers.
Curl Curl to Manly	121,499,930	964 cords 106 ft. =594 5 0 0	25,444,476	1,252 13 1	4 2 9$\frac{3}{4}$	0.993	3 19 cords =2 125 tns	227	Fielding and Platt's compound horizontal engine. Wood-fired boilers.
		9,074 5 0 13		19,666 13 2					
	5,812,591,995	& 964 cords 106 ft.							

gross revenue. This left a net revenue of £187,238 or a return of 3.63 per cent on the capital cost. The amount required to meet interest charges was £185,590 18*s.* 7*d.* This added to the working expenses, £80,281 14*s.* 8*d.*, brings the total charges to £265,872 13*s.* 3*d.*, or a credit balance of £1,646 13*s.* 8*d.* on the year's transactions.

Rates and Charges.—In respect of land and houses of an annual value of less than £20 an annual rate of 10*s.* is imposed, above that value a rate of 6*d.* in the £ on the assessed annual value is made. The rate at which water is supplied by meter is 11*d.* per 1000 gallons up to 10,000,000; 10*d.* from 10,000,000 to 20,000,000 and 9*d.* for any further quantity. Fees are charged in lieu of meterage for working small motors, and in all small trades, washing vehicles, building operations, and stock. Water for gardens where a hose is used, is invariably by meterage.

Meterage.—The board owns, and has now hired out to consumers, 25,000 meters. The meters are fixed by licensed plumbers. The pattern adopted as a standard is of the inferential type, being a modification of the turbine meter patented by the hydraulic department of South Australia in 1887. It is of gun metal and brass throughout, simple in construction, and cheap in price. It is made in sizes ranging from ½ inch to 6 inches. In the larger sizes a by-pass, controlled by a small meter is insisted upon to register the smaller flows. The by-pass is put into work by a patent hydraulic valve.

Free Supplies and Waste Water.—Water to the value of £30,661 is annually granted free of charge. The services so benefited are street watering, flushing gully shafts, hospitals, charitable institutions, fire stations, shelters, urinals (public), parks, the Botanic gardens, fountains, tram-tracks, municipal horse-troughs, public baths, fire extinction (estimated at £84 last year) and the royal navy ships. A large staff of waste water inspectors is engaged in making a strict house to house inspection, and in some districts Deacon's waste-water meters are established, with good results. It can be fairly stated that there now exists very little waste.

Consumption of Water.—The population supplied by the Sydney Water Works is estimated at 668,940. The volume of water consumed during the last year, was 9,819,651,727 gallons, as recorded by the Venturi meter at Prospect, the daily average consumption, 26,903,155 gallons, and the daily per capita consumption, 40.21 gallons, practically the same as that of the previous year. In 1888, the year of the board's inception, the average daily consumption was 8,144,169, and the per capita consumption 27.49 gallons.

Cost of Pumping.– The volume of water pumped during the year at the various stations was about 5,800,000,000 gallons. The full details of cost will be found in tables on pages 416 and 417. The expenses charged are those actually involved. No allowance for depreciation of machinery has been added, but the cost of all repairs, and annual over-hauls, are included.

Electrolysis.– In view of the possibility of damage being caused to the mains by electrolysis a periodical survey has been inaugurated and systematic investigations are made. Connections between the tram-way rails and the water mains were effected to enable the tests to be made, and testing stations established throughout the area served by the electric tram-way system. The mains were tapped, $\frac{3}{4}$-inch screw brass plugs inserted, and end of cable secured thereto by a thimble and nut. At the rails copper bonds were supplied and fixed by the Tramway Department, and the ends of cables soldered to them. For observing, stop-cock boxes are used, each fitted with two terminals from which insulated copper cables are led to the rail and pipe respectively. The tests have indicated the points where danger to the pipes may be looked for. So far no evidence of any electrolytic action, caused by leakage from the tram rails, has been observed.

Telephonic Communications and Daily Records.– Telephonic communication is established throughout the system, reaching from Cataract dam to the head office, and all the principal offices, turncocks, and pumping stations are connected with the central exchange. Returns are daily made to the head office of river flows, rainfall, temperature, discharge into Prospect, discharge from Prospect, and heights of water in all service tanks and reservoirs. Electrical indicators are fixed in all pumping stations connected with the reservoirs or tanks which they fill, and the correctness of the recording instruments is checked by a call from the local turncock.

Cost of Works.––Attached hereto is a complete return of the cost of all works, made up to the end of last financial year.

Prospective.—Many large works of augmentation have recently been authorized, and further improvements, including more storage within the catchment area, are contemplated. The tendency of the community is not fortunately towards lavish consumption, but besides climatic reasons, the extending practice of irrigation, the development of the sewerage system, the increase of industrial manufactures and the growth of Sydney as a port, make it imperative to look well ahead and secure an abundant water supply.

Classification of Capital Expenditure on Water Supply Works, 1909

	PUBLIC WORKS DEPARTMENT EXPENDITURE		BOARD'S EXPENDITURE				TOTAL
	From Loans	From Revenue	From Loans	From Public Works Fund	From Revenue	City Council Works	
	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.
Main Water Supply Works—							
Surveys and preliminary engineering expenses —Nepean scheme	57,515 4 8	9,925 10 3	.....	.....	.....	.....	67,440 14 11
Survey of catchment area	.....	.....	1,111 14 4	.....	193 7 2	.....	1,305 1 6
Cataract Dam, including resumptions on catchment area, £34,192 3s. 10d	382,973 19 0	62 7 8	272 15 10	1,289 13 2	.....	.....	384,598 15 8
Cataract Catchment Area	.....	.....	.....	12 12 0	.....	.....	12 12 0
Pheasant's Nest Division Weir	5,685 12 6	.....	.....	.....	.....	.....	5,685 12 6
Broughton's Pass Division Weir	13,556 4 0	.....	.....	.....	.....	.....	13,556 4 0
Menangle Weir (moiety charged to Board)	694 14 4	.....	.....	.....	.....	.....	694 14 4
Canals, tunnels, aqueducts and piers	1,070,661 17 0	.....	.....	.....	.....	.....	1,070,661 17 0
Canals, tunnels, land resumptions	40,816 13 8	.....	2,281 2 7	.....	.....	.....	43,097 16 3
Upper Canal—Improvement works by Board	.....	.....	77,142 9 7	4,374 16 5	.....	.....	81,517 6 0
Lower Canal—							
Raising and lining	.....	.....	101,118 12 9	.....	.....	.....	101,118 12 9
Sundry improvement works	.....	.....	7,332 6 3	.....	.....	.....	7,332 6 3
Boothtown syphon	.....	.....	18,466 9 8	.....	.....	.....	18,466 9 8
Cottages for maintenance men, officers' quarters, etc., Prospect, canal and catchment area	8,931 9 1	.....	8,672 16 9	19 10 7	.....	.....	17,623 16 5
Prospect Reservoir, including land resumptions £48,445 7s. 1d	671,434 11 1	.....	27,132 16 2	.....	.....	.....	698,567 7 3
Prospect Pumping Plant	.....	.....	9,959 4 8	.....	.....	.....	9,959 4 8
Main Pipe Line—pipe head to Crown street	288,000 16 10	.....	12,221 5 5	.....	.....	.....	289,222 2 3
Duplicate 72-inch main to Potts' Hill	74,533 13 6	.....	1,295 17 5	524 3 9	.....	.....	76,353 14 8
Potts' Hill Reservoir	107,168 4 8	.....	8,165 8 6	43 4 7	.....	.....	115,376 17 9
Duplicate 48-inch main, Potts' Hill to Crown street	157,657 10 3	.....	1,590 8 4	61 19 7	.....	.....	159,309 18 2
Menangle scheme	.....	.....	14,027 9 9	.....	.....	.....	14,027 9 9
Sundry surveys	.....	.....	58 18 3	.....	.....	.....	58 18 3

Main Water Supply Works (Northern Suburbs)						
Submarine main, Dawes' to Milson's Point	3,209 4 8					3,209 4 8
Pipe-line, Potts' Hill to Ryde	83,995 10 4		3,482 15 6			87,478 5 10
Pumping Main, Ryde to Chatswood	15,610 5 5		1,025 7 8			16,635 13 1
Surveys, designs, etc.	10,896 3 7	296 11 8				11,192 15 3
Land resumptions	6,037 12 2		462 7 5			6,499 19 7
Duplicate main pipe head to Ryde	80,504 16 10		3,199 2 5			83,703 19 3
30½-inch steel pumping main, Ryde to Ryde Hill			9,857 19 4			9,857 19 4
12-inch pumping main, Chatswood to Pymble			13,896 10 4			13,896 10 4
15-inch pumping main, Ryde-Wahroonga			35,640 1 9			35,640 1 9
Sundry works			1,189 16 8			1,189 16 8
Service Reservoirs—						
Crown Street, including land, £20,000			892 4 0		40,000 0 0	40,892 4 0
Paddington, including land, £12,137			476 0 2		27,070 0 0	27,546 0 2
Woollahra			401 0 2	133 19 0	10,000 0 0	10,534 19 2
Waverley	10,598 19 7		832 4 10			11,431 4 5
Centennial Park, including rising main from Paddington reservoir and outlet mains, £11,938 17s. 11d.	76,134 2 5		12 10 0			76,146 12 5
Ryde and Chatswood	18,658 18 3		86 13 9			18,745 12 0
Petersham, including land, £3,052 18s. 6d.	15,949 14 9		121 5 4			16,071 0 1
Ashfield			4,870 1 1			4,870 1 1
Ashfield land for additional reservoir			288 15 0			288 15 0
Harrisville, including caretaker's cottage, £748 18s.			6,809 19 5			6,809 19 5
Vaucluse land resumption claim unsettled			4,199 3 6			4,199 3 6
Wahroonga, including caretaker's cottage, etc. £843 10s. 10d.			6,596 8 9			6,596 8 9
Pymble			4,477 17 5			4,477 17 5
Beecroft			4,788 19 5			4,788 19 5
Mosman, Bradley's Head road			2,056 16 10			2,056 16 10
Mosman, Spit-road	9,652 18 10		79 9 11	18 0 3		9,750 9 9

Classification of Capital Expenditure on Water Supply Works, 1909—Continued

	PUBLIC WORKS DEPARTMENT EXPENDITURE		BOARD'S EXPENDITURE				TOTAL
	From Loans	From Revenue	From Loans	From Public Works Fund	From Revenue	City Council Works	
Service Reservoirs—Continued	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.
Telephone line—Ryde to Wahroonga, Pymble and Hermitage	.....	.....	198 1 1	.....	.....	.....	198 1 1
Indicator line and records, Ryde, Wahroonga, Pymble and Hermitage	.....	.....	394 15 1	.....	.....	.....	394 15 1
Randwick	.....	.....	6,396 4 8	.....	.....	.....	6,396 4 8
Crow's Nest, North Sydney, land	.....	.....	1,441 12 0	.....	.....	.....	1,441 12 0
Drummoyne, land	.....	.....	576 4 0	.....	.....	.....	576 4 0
Hornsby, land	.....	.....	170 0 0	.....	.....	.....	170 0 0
Dundas, land	.....	.....	126 11 0	.....	.....	.....	126 11 0
Water Supply Depôts—							
Leichhardt, including land, £2,696 1s. 2d.	2,696 1 2	.....	711 1 0	.....	.....	.....	3,407 2 2
Crown street Depôt Buildings and sundry works	.....	.....	7,794 16 9	.....	.....	.....	7,794 16 9
Park-road, irrespective of value of land	.....	.....	518 9 0	.....	.....	.....	518 9 0
Carlow street, North Sydney, including land, £1,491 12s. 9d.	.....	.....	2,284 12 4	.....	.....	.....	2,284 12 4
Pumping Stations—							
Ryde—							
Buildings and sundry works. £24,567 5 7 Machinery and Plant..... £40,371 14 6	26,706 17 2	.....	38,023 19 5	208 3 6	.....	.....	64,939 0 1
Crown street—							
Buildings and sundry works. £14,911 16 10 Machinery and Plant..... £33,207 4 11	.....	.....	45,894 1 9	.....	.....	2,245 0 0	48,139 1 9
Chatswood—							
Buildings and sundry works. £1,117 5 7 Machinery and Plant..... £3,692 7 2	.....	.....	4,809 12 9	.....	.....	.....	4,809 12 9
Carlton—							
Buildings and sundry works.... £92 17 7 Machinery and Plant..... £2,157 4 2	.....	.....	2,231 5 3	18 16 6	.....	.....	2,250 1 9

Pumping Stations—Continued						
Mosman, temporary pumping station			376 13 0			376 13 0
Water Mains			995,411 18 8	1,715 0 11	166,563 16 11	1,163,690 16 6
Manly Water Supply	37,477 11 9		13,948 13 7	1 6 6		51,427 11 10
Botany Leases—drains, channels, etc			5,307 18 2			5,307 18 2
Board's Head Office—Moiety			33,044 6 4			33,044 6 4
Board's Meters			71,813 11 2			71,813 11 2
Sundry Plant, surveyors' equipment, etc			18,808 14 10	54 12 0		18,863 6 10
Hermitage scheme			45,904 0 1			45,904 0 1
Liverpool Water Supply	351 2 5	1 14 8	19,834 11 1			20,187 8 2
Campbelltown Water Supply	263 10 6		7,989 15 8			8,253 6 2
Camden Water Supply	36 2 0		10,581 18 6			10,618 0 6
Smithfield Water Supply			2,648 0 8			2,648 0 8
Pipes and Machinery on hand ex Penrith scheme			27,318 3 6			27,318 3 6
Recoverable from sundry debtors			33 5 5			33 5 5
	3,278,410 2 5	10,286 4 3	1,750,186 3 8	8,475 18 9	193 7 2	245,878 16 11	5,293,430 13 2

Is it good policy to treat an entire water supply to make it good for boiler use, cost and suitability for other uses considered? Or would it be better policy and practical, where the natural supply was not a good boiler water, to treat boiler supplies individually and separately?

Mr. William Miller Booth: I estimated the cost of softening a water supply the hardness of which was 26° Clark, about 500,000 gallons per day, this amounted to $30 per day to *completely* soften the water, which I considered prohibitive for that town. I took a part of this water that is used in a large manufacturing concern, and softened it to a hardness of about 1½ grains per gallon, and found that it was totally inefficient for use in the boiler plant, that is, that a water of that hardness completely softened foamed so in the boilers that it could not be used; so that to soften a water of 26° hardness at a cost of $30 a day seemed to me in that town perfectly useless and out of the question. Partial purification has proved very effectual in the plant mentioned.

In this connection I figured about how much it would cost to soften the supply of the city of Syracuse, 13,000,000 or 14,000,000 gallons a day; that water contains principally carbonate of lime, and could be softened very cheaply indeed, at a cost of about $20 a day. The water has a hardness of about 5° Clark. The feasibility of softening depends very much upon the character of the water. If the water can be treated with lime cheaply I think it would be a very good idea to soften it generally speaking, because the lime and magnesium are taken out and nothing is returned to interfere with boiler use. On the other hand, if soda ash is used as a treatment the sulphate of soda foams in the boilers, so that if the water is high in sulphate hardness it costs a great deal to treat, sometimes as much as 5 or 6 cents per thousand gallons, in which case it is entirely out of the question to soften water a large portion of which may be used simply to flush streets and closets.

Mr. William Holmes: It is likely that absolutely pure water, free from all dissolved gases, would make a good boiler water. Such

a water however, is not a practical possibility in boiler plants. Ordinary distilled water invariably contains both oxygen and carbonic acid gas in solution and under these circumstances is extremely corrosive to iron and steel. The addition of a small amount of alkalinity, such as $\frac{1}{2}$ to 1 grain of soda ash or caustic soda per gallon, will completely neutralize the corrosive tendencies of distilled water. As for hardness it cannot be said that some degree of hardness is preferable to the complete absence thereof. There is no protective virtue whatever in calcium or magnesium compounds, which is due to their content of calcium or magnesium. Any protective action which they may exert is due to the particular radicle with which these metals are combined. For example, calcium carbonate, which is undoubtedly protective, owes its efficiency not to the calcium but to the carbonate radicle, and sodium carbonate will prove equally effective besides possessing the great advantage of being non-scale forming.

Mr. Albert Blauvelt: Depends on the amount of boiler water used as compared to total amount pumped. In general the water supply should be treated to be potable, leaving boiler users to do more or not as they choose.

Mr. H. G. H. Nutting: Treat separately.

Mr. Ernest McCullough: In my opinion it is better to treat each class of waters separately on account of the cost. If the water requires treatment in any case then it is as well to have all the treatment at one time to save the expense to individual users of boiler supply. Usually it is more expedient for each user to treat his own supply of boiler water.

Mr. George J. S. Collins: In my opinion it would not be good policy to treat an entire water supply to render it suitable for boiler uses, from the fact that cost of rendering such supply suitable for this purpose compared with the small proportion of the total supply required for this use would not warrant the expense in general, although there may be exceptions in small places. In some cases the treatment might render a hardship to manufacturers.

Waters unfit for boiler purposes can usually be much improved by the intelligent use of *proper* boiler compounds, and in some cases, depending on the nature of the water and the compound used, such treatment can be effected most satisfactorily. In using the term

"proper boiler compound" I would exclude thereby the vast majority of proprietary compounds upon the market, and limit this to embrace those compounds of demonstrated efficiency, having a definite chemical reaction with those constituents of the boiler water which it is desired to neutralize or remove.

On account of the varying conditions entering into the determination of the quality of boiler water, no hard and fast description of "good boiler water" could be given. A water absolutely free from hardness and alkalinity would not be ideal for boiler uses. Such water would be probably strongly corrosive on account of the dissolved gases contained therein. A certain mild degree of hardness or alkalinity is desirable. There is a good material for the treatment of Missouri River water manufactured and one which is getting to be generally used in this territory.

MR. L. M. BOOTH: Yes. Generally speaking, it is good policy to treat an entire water supply to render it ideal or suitable for boiler purposes, that is, providing the rendering of the water suitable for boiler uses does not render it unsuitable for other uses. We have in mind particularly the treatment of water with boiler compounds, many of which would render a supply totally unfit for general use. Where the "treatment" consists of softening by means of lime and soda ash, it is unquestionably good policy to treat the entire supply. If this treatment improved the water for boiler feed alone, then there might be some question, but the softening process improves a hard water not only for boiler feed purposes but for practically every use to which the water can be put, except possibly sprinkling the streets, fire or kindred uses. Softening a hard water to make it suitable for boiler use will also render it practically non-corrosive to the city mains and to the plumbing in the individual establishments. It will make it much more suitable for washing clothes and in fact for every use where soap consumption enters. In a properly designed water softening plant, the removal of bacteria is so great even without sand filtration that the sanitary quality of the water is improved 80 per cent to 90 per cent.

Even where the entire city supply is softened so as to fit it for boiler purposes, it undoubtedly will pay large consumers of water in many instances to install their own softeners. It is not likely, nor is it to be expected that the city should furnish water and should soften the same at a cost comparable with the cost to the individual plant of pumping a well and softening water of about the same general char-

acter as the city water. Furthermore, the mere fact of having an independent supply of water at his disposal is a matter of considerable value to the large manufacturer. For the small boiler plant, on the contrary, soft city water will be a great boon as the expense of installation of efficient apparatus for a plant of less than 100 h.p. is apt to be prohibitive. The cost of softening hard water averages about 2 cents per 1000 U. S. gallons, whereas, the saving to the population from the use of soft water would more than counterbalance this increased cost of city water.

Mr. William Miller Booth: I estimated the cost of softening a water supply the hardness of which was 26° Clark, about 500,000 gallons per day, this amounted to $30 per day.

Mr. C. A. Brown: It seems to me that this question is one that can hardly be discussed intelligently and expect to cover its many phases in the limit of time allowed. It is a large subject. There are a number of factors that enter into a problem of this kind each of which must be given due consideration. The important bearing that the character of the water has was well indicated by the remarks of the last speaker, and plays a very important part. The quantity of water which is employed for boiler purposes will necessarily be a large factor. The amount of solids other than scale formation which the water contains will necessarily play a large part; so that taking the matter as a whole I do not believe that any categorical answer can be made to the question. The company with which I have the pleasure of being connected is probably one of the largest users of softening processes in the United States and possibly in the world. We purify our water at many points for boiler purposes; and in some of our plants these softened waters are used for drinking purposes as well.

Now we have found that in some instances it is impractical to purify certain supplies and the amount of solids other than scale formation, even though the water be properly softened, renders such waters largely unsuitable for boiler purposes, and we have in such cases been forced to go to other sources of supply.

Again, the softening of the water supply is a matter that has received a great deal of attention, particularly where it is to be used for boiler purposes; and I think has not received sufficient attention where it is used likewise for city supply.

Oberlin (Ohio), I believe, was the first town in the United States

to completely soften the water supply. There were some other places where they had used partial softening to remove the temporary or carbonate hardness; but at Oberlin it was decided to remove all of the hardening compounds as far as practicable. That was done. There were very few large steam users in that town, but those who were using water for boiler purposes experienced great relief from that process. The process was not adopted merely for the purpose of fitting the water for boiler use, but with reference to the city at large, it was a commercial problem, and has been proven advantageous.

I think that the question is one that will have to be suited to each individual location after duly considering all local conditions, the quality of the water, the quantity used for boiler purposes, and all of the other factors which would enter into that, before you could give an intelligent answer to a question of that nature.

MR. BROWN: It might be suitable for other purposes and still contain sufficient solids of known scale producing qualities which would interfere with its use in the boiler and its practical softening, as stated by the previous speaker.

Is there any saving in maintenance and operation of a water works by use of power driven trench pumps in laying mains and making repairs?

MR. WESTON: We had an experience with power trench pumps this last month. We have been laying a sewer on the Island of Nantucket. There was great difficulty in getting enough service out of the retired sea captains working a diaphragm pump sufficient to keep the water out of the trench. One ingenious inhabitant thought he could rig an ordinary 1 h.p. gasoline motor to work this pump. This was done very successfully. The whole apparatus cost about $49.50. This gasoline engine works day and night and does the work of four men, saving at least $6 a day. I do not think it is beyond the possibilities of any water department to have one, and certainly it pays for its cost in one or two weeks' work when the delays incident to a wet trench are taken into account.

MR. HAWLEY: I have a couple of centrifugal trench pumps directly connected to gasoline engines, which I have found exceedingly useful. The pump and engine are mounted on a short plank platform, the

platform being set on a pair of low trucks. It is thus readily hauled to the vicinity of the place where it is to be used and, if necessary, four men can pick it up and carry it to the trench. I have found these outfits much more dependable than the ordinary trench pump and much cheaper to operate.

Mr. E. E. Davis: I have a trench pump at home operated by a gasoline engine. It costs anywhere from $4.00 to $6.00 to have the water baled out by hand, whereas with the gasoline centrifugal pump and gasoline engine I can take the water out in an hour or two at a trifling cost. It is mounted on a truck, and the same wagon that hauls the material from the store-house pulls this truck fastened on behind. The only trouble with a gasoline engine is, as you gentlemen all understand, that you never know when it is going to go back on you. Nobody on earth can tell why it sometimes refuses to move. In building a new flume from the settling basin down to the pumping station the contractor used a gasoline engine driven centrifugal pump, and there was no trouble to keep the water down. Otherwise they would have had a great deal of trouble.

Mr. Wehr: We have been pumping by hand out on the outskirts, but we have come to the conclusion that the only way to adequately pump out a trench is by using a trench pump. We had a rather ingenious equipment in Baltimore which we used on long lines but not on short extensions because of the difficulty of transporting it. We have on a truck a gasoline engine with an air compressor, using an air hammer for caulking and an air drill for drilling when we get into rock. This equipment we have on a truck which one horse pulls. We are now getting ready to put it on an 18 h.p. automobile truck, using the automobile engine both for propelling the machine from point to point and also operating the air compressor. We will equip the same with a centrifugal pump for use in wet places. It will thus be easily transported across the country in the territory that we serve.

Mr. Wiles: Take an ordinary water ditch and ordinary water mains, where we have a limited amount of water, say an amount that with an ordinary trench pump can be lifted out in fifteen or twenty minutes, is it feasible to use a gasoline pump on that trench with economy? You can only run it say ten or fifteen minutes until you have to stop because you have run out of water. You do not have water enough to keep it going all the time. In the ordinary trench

many of us find the water is not sufficient to support a gasoline engine pump and especially when the ordinary hand pump if it worked with diligence will take out the water in ten or fifteen minutes. I doubt whether under such conditions it is worth the time and trouble to put in a power pump.

MR. E. E. DAVIS: All of you gentlemen who have any experience with the centrifugal pump probably know that you can choke down the suction or discharge, and thus reduce the flow of water pumped in the event that you want to hold down a small stream while caulking or making a connection. You can bring it down to a minimum. I have four centrifugal pumps, each capable of pumping 4,000,000 gallons every twenty-four hours, driven by electricity. I tried choking down the discharge and suction, and found I could reduce the flow into the reservoir to 2,000,000 gallons. You can bring it down until the pump will be almost churning.

MR. ALBERT BLAUVELT: Only for cities of over one quarter million inhabitants.

MR. H. G. H. NUTTING: Yes, by all means. It costs $60 to convert an ordinary trench pump into a motor driven one; interest, maintenance and depreciation would be $6 per year. Cost of power would be very little. You can save cost on one repair job.

MR. ERNEST MCCULLOUGH: There is a great saving in the cost of laying mains in wet ground when power pumps are used to keep the trenches dry. The trenches must be kept dry if good work is to be done and a small power pump is much more cheaply operated than a hand power pump, such as is often used. Cheap power pump outfits for this work are on the market and I have used two makes with great satisfaction.

MR. A. N. FRENCH: I have used a power driven trench pump with good results, but for ordinary repair work it requires too much time to get ready and transport to the job.

MR. WESTON: The pump at Nantucket is a diaphragm pump and can work whether the water is flowing to the suction freely, or not. When there is a low flow of water in the trench it will work just the same. The motor is of Chicago make, one horse power air cooled,

and requires no transportation of water for the cooling of the cylinder. It requires about two gallons and a half of gasoline to run it a ten hour day.

Can mechanical filters be successfully washed with well waters not previously filtered, though clear and comparatively pure?

Secretary Diven: I suppose the idea is to save the $2\frac{1}{2}$ or 3 per cent of filtered water that is ordinarily used for washing filters by using some other water in its stead?

Mr. Chester: I cannot understand how washing with unfiltered water can effect a saving in the quantity of water. I have known instances where it was economy in first cost to wash with unfiltered water; take, for instance, a filter placed near or just below a service reservoir where in order to overcome the necessity of pumping water to a higher level, unfiltered water is used for wash purposes. The state board of health of Pennsylvania have approved for a given length of time this method at Freeport, Pa., but it is intended ultimately to install a wash pump and possibly a tank on a tower that filtered water may be available for this purpose.

Mr. Diven: Would that not come under the same head as the emergency intake proposition? Not objectionable if the unfiltered water is good; but if good enough to wash filters with, why not good enough for the domestic supply?

Mr. Chester: I do not think it is the best practice. It was only done temporarily.

President Alvord: Some of the questions in our Question Box raise very large problems, and necessary data is not always furnished to discuss them intelligently; but these questions are all asked in good faith and I think they bring out the fact of the complexity of the problems that some of them involve, so I believe it is desirable for us to give them attention for that reason.

Mr. Marion E. Jones: Our filters are placed above the reservoir, and we have washed with unfiltered water. We found it very unsatisfactory and very expensive; but we have been forced to wash our fil-

ters in that way. We figure that it costs us about 24 per cent of our pumping expense to wash the filters at the city of Gadsden, Ala.

MR. E. C. LEVY: Personally, I would not think it desirable to wash mechanical filters with water which was not above suspicion. Of course everything would depend upon just what the "comparative" purity was of the water. It seems to me that it might be allowable to conduct the first part of the washing with such well water as mentioned, provided the process was finished by washing with pure water.

MR. H. G. H. NUTTING: Yes.

MR. WILLIAM HOLMES: No.

What is your experience with the use of oil for fuel, its cost based on horse power developed, evaporation or per 1,000,000 gallons pumped 1 foot high, making comparison if possible, with the same work done with coal?

MR. CHESTER: My experience as to the evaporative value of coals in this country is that they vary almost 100 per cent. Take Pocahontas coal we can get 10 pounds of water evaporated per pound of coal consumed when carefully fired; but with Southwestern Illinois and Wyoming coals if we get an evaporation of 5 pounds of water per pound of coal consumed we do well. Coal varies almost in the ratio of its geographical location; this is not, however an invariable rule; but we may say that Indiana coal is good for 6 pounds, Ohio coal is good for 7 pounds, Pittsburg coal for 8 pounds, Pocahontas coal in Virginia 9 to 10 pounds. We can crowd our Pittsburg coal to 9 pounds, and increase each coal mentioned 1 pound by careful firing. At St. Joseph, Missouri, the plant changed over from coal to oil, and found the latter very much cheaper. It was Kansas oil and evaporated almost 15 pounds of water per pound of oil consumed. They had previously burnt Iowa coal, which is about the same as southwestern Illinois coal, evaporating 5 to 1. The price of oil being low as compared with coal they effected a considerable saving in the commercial outlay in the operation of their plant.

Different oils have different thermal values and different evaporating efficiencies. I have never known oil to go below 12 pounds of water evaporated to 1 pound of oil when there was anything like a proper introduction of it under the boilers; and I have never known

it to go over 15 pounds. So I think we can safely say that oil if it is introduced properly will run from 12 to 15 pounds of water to each 1 pound of oil consumed, and that coal will yield 5 to 10 pounds of water; but in making any comparison such as is asked for in the question we ought to first find out the thermal value of the coal and oil we are going to burn.

Mr. F. L. Johnson: I am not qualified to speak upon the comparative value of coal and oil, for I never burned a pound of oil in my life, but I have burned hundreds of pounds of liquid fuel, water gas tar, having a thermal value of about 17,000 heat units per pound, and had no difficulty in getting an evaporation of 15 pounds of water to every pound of fluid fuel. Most of the oil contains 19,000 heat units per pound, and you should be able to get nearly 17 pounds evaporation from it; but the best records we have seen run a little over 15 pounds. Where coal will evaporate 10 pounds of water per pound, oil is worth 2 cents a gallon, with coal at $4 per ton; if your coal will only evaporate 5 pounds of water per pound of coal, and the coal is worth $2 a ton, then your oil is worth 2 cents a gallon for fuel.

The whole thing hinges upon the respective comparative price of the oil and the coal, and the efficiency with which it will burn. When looking over most of the reports of the tests in burning oil I have been convinced thoroughly that altogether too much air was admitted to the furnace with the fuel, cooling the gases and impairing the efficiency of the combustion, not only of the combustion but of the furnace itself.

Mr. A. E. Walden: The following figures have been taken from practice and I hope will be of value in this discussion.

Comparative Cost of Oil as Fuel with Coal

Coal per Ton	*Oil per Barrel*
$5.00	$1.40
4.75	1.34
4.50	1.27
4.25	1.20
4.00	1.12
3.75	1.05
3.50	0.99
3.25	0.91
3.00	0.84
2.75	0.77

The actual evaporation is from 15 to 17 pounds water per pound of oil; coal only from 6 to 10 pounds water per pound.

With oil, 4 to 5 per cent of steam is required to vaporize and handle the oil.

Fire room labor is reduced to a minimum with oil, as compared with coal and handling expenses.

Pumps or supply system should be provided with automatic overflow and regulating valve.

Oil may be fed with compressed air with better results, but first cost is greater.

MR. JOHN R. DOWNS: The following from the *Panama Canal Record* may be of interest in this connection. The commission has a contract with a California company to furnish fuel oil at $1.10 per barrel of 42 gallons at 60° F. The oil to contain not more than 2 per cent water and sediment, the price is for oil delivered into commission's tanks at point of consumption.

Coal—run of mines "Pocahontas"—delivered at point of consumption, except at tide water, costs $6.25 per ton.

The commission finds that except at tide water, where the cost of coal is a little less than $6.25 per ton, oil is more economical.

The table shows the efficiency obtained with different installations. The highest efficiency is obtained at station "A," where the air for combustion is preheated in fire brick passages.

Burners are steam spray type, steam used under full boiler pressure, oil used under head of 30 to 100 feet.

STATION	BOILER EQUIPMENT	PER CENT RATED POWER	EFFICIENCY OF BOILER	POUNDS WATER PER POUND FUEL EVAPORATED FROM AND AT 212°F
			per cent	
A	Six horizontal fire tube	90	77.6	14.22
B	Twelve horizontal fire tube	101	76.5	13.69
C	Six horizontal fire tube	98	74.1	13.28
D	Six Keeler water tube	95	71.7	13.07
E	Two Sterling water tube	115	73.8	12.82
F	Two scotch marine	170	75.2	12.80
G	Six Abendroth and Root water tube	118	69.5	12.56
H	Three verticle fire tube	173	68.5	12.50
I	Six horizontal fire tube	79	70.0	12.49
J	Five Manning fire tube	71	63.3	11.75
K	Three locomotive type	198	61.6	11.23
L	Two locomotive type	65	39.0	7.12

After several months of experience two additional tests were made on stations C. and L. Test B under normal working conditions. Test C with special firing. The principle item is control of the air supply for combustion.

STATION	BOILER EQUIPMENT	EVAPORATION FROM AND AT 212°F. POUNDS WATER PER POUND FUEL		
		Test A. Original test	Test B. Normal conditions	Test C. Expert firing
C.	Six horizontal fire tube	13.28	13.93	14.40
L.	Two locomotive type	7.12	10.75	13.11

Can you give some information as to tests that have been made as to proper depth to lay mains to prevent freezing; are they not laid often deeper than necessary?

Mr. H. G. H. Nutting: Cannot overdo this within reasonable limits. At Fort Atkinson, Wis., we lay them 6 feet.

Mr. Edward L. Hatch: We lay our mains (Stamford, Conn.) 4 feet deep and have no trouble with taps freezing.

Mr. Ernest McCullough: I believe that in many cases mains are laid much depeer than is necessary for the purpose of preventing freezing but know of no tests made to determine this matter. I have known of pipes laid deep enough to prevent freezing and passing successfully through several winters having their joints opened by the use of heavy steam rollers when the streets were paved.

Mr. Albert Blauvelt: Do not believe they are often laid deeper than necessary. Our experience is usually the other way.

Have you had any "red water troubles"—that is, complaint of red or rust color in hot water. If so what do you attribute it to, and what remedies have you applied? If water is filtered, what if any effect has filtration had on this trouble? Is the trouble uniform throughout the distribution system, or only in certain sections? Do you note any difference due to the material of service or house pipes?

Secretary Diven: This was extensively discussed under Mr. Whipple's paper "Hot Water Troubles." Mr. Whipple's paper also answers some of the questions

MR. F. S. SHIELDS: We beg to state that the only trouble reported by consumers of this character seems to come from old pipes inside of premises and due to rust after the galvanized coating has rusted away. As our supply of water is perfectly filtered, we have no comparison as to what the effect of unfiltered water, but we have been told by consumers who were supplied formerly with crude water from the N. O. Water Works Company, that they did not have this trouble; the pipes were evidently covered with mud. As to the trouble being in certain sections, it is in scattered houses, doubtless where the material of the pipes is inferior.

MR. H. G. H. NUTTING: Have had little trouble from this, have always laid it to local conditions on premises.

MR. ARTHUR N. FRENCH: We had have considerable trouble with "red water" due, in our case, to the growth of Crenothrix Kuhniana in ground water. It troubles us in certain sections of our town, and the only remedy we have made use of is frequent flushings of the mains. It does not seem to be worse as a general thing in hot water than in cold, though there are a very few cases where the hot water in a dwelling house will have this trouble, and the cold water will not. The next house alongside may not have any trouble with hot water. We are to give up our supply and take "Metropolitan water," so we are not looking for a remedy.

Do you allow joint connections with other sources of supply for fire services to factories etc.? If so have you experienced any trouble by back pressure from such systems contaminating the city supply?

MR. ALBERT BLAUVELT: Fire service check valves may be liable to contaminate the city supply by back pressure. Better check-valves are needed, and also more care against employing a contaminated supply in company with the city supply.

This is not wholly an insurance subject, but is principally a board of health subject.

MR. E. C. LEVY: I have only recently taken up the question of allowing fire systems in factories to have any connection whatsoever between city mains and other sources of water supply. My own position is that such connection should by all means be avoided. I feel entirely unwilling to allow any such connection, regardless of protection which is supposed to be furnished by check valves or hand-operated valves. I cannot see why abundant fire protection cannot

be afforded by installations in which public water supply alone is called on, certainly in so far as sprinkler systems are concerned.

Replying specifically to your question, I do not know of any instance in our city in which there has been actual contamination of our supply, but I regard it as a matter of great good fortune that such has not occurred, in view of certain connections which I have found within the past few weeks.

Mr. Arthur N. French: We have been allowing such joint connections, and had one instance of forcing river water into our pipe system. Such joint connections are being done away with, or being securely guarded with check valves.

Mr. Metcalf: It may be of interest to mention one case that came to our attention where, while we did not wish to have any connection between the two sources of supply, as the manufacturing company's supply was a polluted one, yet it bore very heavily upon the company not to permit such a connection. Finally an agreement was arrived at that it should be permitted, with the understanding that when the company made use of the polluted supply to test its fire pumps, the main stop-gate on the line should be closed, and as a precautionary measure that there should be two check valves outside of this gate valve which should be inspected by the Factories' Mutual Inspection Agent every time that he inspected this factory, and that he should examine the openings that were made in the pipe line between these check valves on both sides to make sure that they were reasonably tight. I might add that in this case the difference in pressure was not very great on the two sides of the valves, and it was thought safe with these precautions to give the manufacturer the right to make his connection, although it was recognized that it was undesirable.

Secretary Diven: You spoke of the pressure being uniform. Suppose the water was shut off temporarily from the city mains, would there not be danger of the polluted water getting into them?

Mr. Metcalf: Unquestionably, yes.

What should the superintendent's salary be in proportion to net receipts or extent and cost of work.

MR. ERNEST MCCULLOUGH: The superintendent's salary is nowhere based on net receipts or cost or extent of works. Political considerations generally fix this matter. He should get as much pay as men of equal ability in equally responsible positions.

MR. ARTHUR N. FRENCH: As large as he can prevail upon the water board to make it.

What has your experience been with power calking, i.e., calking lead joints in cast iron pipe with pneumatic hammer or calking tools?

MR. ALBERT BLAUVELT: Believe in power calking wherever water works is big enough to stand the expense of the rig.

MR. A. E. WALDEN: I will repeat here an article published in *Engineering News*, and contributed by the speaker.

A PORTABLE COMPRESSED AIR PLANT FOR CALKING PIPE

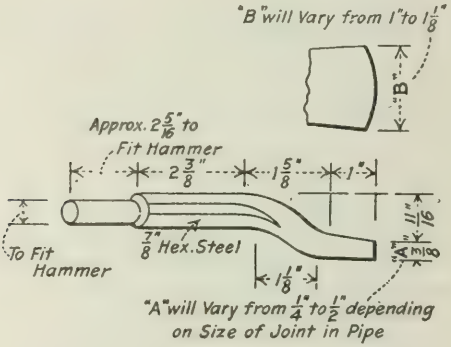
By A. E. WALDEN

In 1906 the Baltimore County Water and Electric Company started to lay about 25 miles of 12, 10 and 8-inch pipe cross country to take care of a section that was supplied by deep wells which had given every evidence of failing entirely and prevented taking on additional consumers, and giving satisfactory service to consumers already connected. It was soon found that expert and rapid calkers could not be secured and a portable compressed air plant for calking, cutting and drilling was purchased and mounted on a truck, which proved a success in every respect, though some trouble was experienced with the gas engine. It was found possible to calk a 12-inch pipe satisfactorily for 250 pounds working pressure in 2½ minutes, the average for all joints being between three and five minutes. The joints were more satisfactory and were tight in every respect. The average actual time for hand calking on this size pipe was 30 minutes, but the all-day average was 45 minutes. At one time two men, with the air hammers, calked between 8 a.m. and 5 p.m. 76 lengths of 12-inch pipe out of a total of 87 pieces laid and leaded. This work was done in cold weather, which made it difficult to get the best results. This line is operating under pressures of from 100 to 250 pounds per square inch depending on the elevation, and so far there has not been a joint leak where the air tool was used. The time required to cut 12-inch pipe was 2½ minutes. The portable plant was made up as follows:

A 6-h.p. gasoline engine was belted to a small duplex air compressor capable of maintaining 70 to 80 pounds air pressure when delivering 32 to 35 cubic feet of air per minute, with storage and cooling tank and a small centrifugal circulating pump for circulating the water through the jacket. The engine was of the single cylinder vertical type, but it was found that a two-cylinder engine

would have been better, and it is possible that one of the small, air-cooled, multi-cylinder, marine engines would have given the best results. The equipment was mounted on trucks, and provided with two lengths, of 150 feet each, of $\frac{1}{2}$-inch air hose connected to a storage tank at two different points so that it would only be necessary to move the machine once in every 300 feet. An air-hammer drill was provided operated from the same equipment capable of drilling up to 4-feet holes. In the niggerhead formation it was possible to drill at the rate of 2 inches per minute.

Two sizes of hammers for calking were purchased, one 3-inch and one 2-inch. The 3-inch hammer was a success, as the shorter-stroke hammer jarred the operator's wrists so that they could not operate steadily. The proper shape calking tools could not be secured from the hammer manufacturers so that it became necessary to have them made up locally. These tools are shown in the accompanying figures. The cost of the entire equipment ready to operate was $665, including engine and truck, all tools, drills, hammers, etc. The usual



Type of Tool Used with Pneumatic Hammer in Calking Pipe. Baltimore County Water and Electric Company.

antipathy of men toward labor saving devices was encountered but the results obtained demonstrated the possibilities of the equipment to do even better work than it did here. The same truck is now to be equipped with a small centrifugal pump for pumping out trenches, etc., and will thus make a very compact outfit. It was found that the construction of the hammer could be improved by providing a spring clip that would snap over a collar on the tool to allow of the tool turning easily in the socket, but so constructed that it would prevent jumping out when starting the joint. In calking where a joint "is poured" if the lead slug is driven in and swedged off (not cut off) with the tool no leaks will occur at a joint calked with the air hammer and it is possible to drive the joint hard enough to crack the bell.

Some additional experience with this method of calking may be of interest, as we had nothing to guide us at the time we purchased a single cylinder gas engine of about 6 h.p., belted to duplex air com-

pressor, mounted on wheels with solid tires on them. However, if it is possible to secure an old automobile, with four-cylinder engine, of about 18 h.p., gearing same to small duplex air compressor, having capacity of 40 cubic feet of free air, at a pressure of about 60 pounds, the equipment cannot be beaten. This is what we are now proposing to do.

Should non-paying water consumers be metered, that is, free public supplies, such as city public buildings, schools, fountains, etc?

MR. TRAUTWINE: My observation of water waste in the city hall in Philadelphia, and in other municipal institutions there, has made me a very hearty supporter of the unanimous voice of the gentlemen who have written in favor of metering all public services.

MR. MILNE: Some years ago our city decided to build a number of ward schools. Our city being unfortunately scattered over a very large area with a small population as compared with the area, it was necessary to build a smaller type of school. The buildings were to be equipped with up-to-date sanitary fixtures. All the older schools in the city had been on a flat rate, every service in the city whether civic or otherwise paying for the supply with the exception of the public drinking fountains. On the completion of the plumbing in one of these schools I went with the inspector to take a look at the work and discovered what I thought would be a very expensive system of flushing the water closets. I talked with the plumbing contractor, who told me that the closets were arranged to flush once every thirty minutes. I made no comment at all, but the next morning I sent my foreman down to put a meter on the closet there.

The first day's operation showed 3400 cubic feet consumption. I had another meter set on another school within a square of the first. I got in immediate contact with the care-taker and told him to watch and shut off the flush immediately at the close of the school and keep it shut off until 8.30 the next morning. I watched that meter very carefully, and the first month the consumption averaged 604 cubic feet; the other meter in the meantime had jumped up to 5000 cubic feet. I then put meters on all the schools and notified the school board that the water rate for the year would be based on the metered consumption. They are all running now at 9, 10 and 15 cubic feet per day, we are still charging on the basis of the average of the central school on which I make my reading. It is up to the care-takers of

the other schools to see that they maintain the same type of service and as efficiently as No. 4. The meter in that case was not for the purpose of decreasing the necessary consumption but to stop waste; and it did it very effectually.

Mr. Albert Blauvelt: By all means they should be metered, to show the difference between use and abuse, whether any charge is made or not. The water works should be able to account for all water pumped as closely as practicable outside of unavoidable leakage, accidental breaks, emergency fire use, necessary flushing, etc.

Mr. A. E. Walden: It is the speakers opinion that all services should be metered, to obtain as nearly as possible a correct record of water delivered.

Mr. F. S. Shields: The sewerage and water board of New Orleans has only been supplying the city with water for about two and a half years, and as there are more free consumers here than anywhere in the world—all public buildings, charitable institutions, schools, quasi-charitable schools, asylums, parks, drinking fountains, horse troughs, etc., and water furnished for flushing closets, it soon became evident that it would be necessary to meter every opening through which water is supplied, whether to paying consumers or to free consumers, except fire hydrants. This has been now practically accomplished and all free consumers—public buildings, schools, asylums and institutions, are read monthly and regular accounts kept and notice given of the reading to the consumers and comment made as to whether the consumption is excessive or not. In this way, the consumption of all these institutions has been very materially cut down and a great saving results to the city.

Mr. Arthur N. French: They certainly should. We are metering them as fast as we are the paying ones.

Your experience in the application of hypochlorite or bleaching powder to water as showing the practical limits with which it can be added to water of different character without noticeable effect upon taste?

Mr. A. E. Walden: After experience with hypochlorite of lime, extending over a period of four years, would say there is no reason

why there should be any odor or taste, if the proper amount of lime is not exceeded. One-tenth of a grain will accomplish, under all ordinary conditions, all that is required, but if the lime is allowed to stand open, or to deteriorate, it is possible that too much lime may be added. It is possible that this question was asked owing to inability to get the definite proper amount, but as there are about 7000 grains in a pound, and 0.1 of a grain of chlorite of lime per gallon is necessary, it is easy to arrive at the proper amount.

Mr. Arthur N. French: We have used hypochlorite of lime in the proportion of 6 pounds of the powder per 1,000,000 gallons of water, with no taste resulting. That is the only amount we have used.

Is leadite a good material for making water pipe joints, and what is the actual saving as compared with lead?

Is it safe with the present experience, to use leadite for cast iron pipe joints, and what are the objections to it, pro and con?

Mr. Hawley: The writer has been using leadite for about five years, during which time about 15 miles of mains have been laid with it ranging in size from 4 inches to 16 inches in diameter and he has also used it for repairs on sizes up to 42 inches in diameter.

Leadite is a very satisfactory material for making joints provided it is properly used. The writer's experience with it has been such that he has abandoned the use of lead entirely except in the case of large sleeve joints where, in cases where the joint room was excessive, he has experienced some trouble. This has probably been due to shrinkage in cooling, together with the too rapid pouring of the joint. The pressures on which he has been using leadite range up to a maximum of 210 pounds per square inch in the distribution system with a large part of the system under pressures ranging from 100 to 175 pounds per square inch. Under these conditions, he believes that the material has been given a pretty thorough test.

Compared with lead it is very easy to manipulate, requiring no special skill. It has its own peculiarities, however, just as lead has, and to be used properly, a man must be familiar with it. The writer knows of a number of people who have tried to use leadite and have not gotten satisfactory results, but in such cases as he has been able to investigate, the failure was due to the methods used.

Leadite, when cast in the joint, is hard and vitreous in nature.

It is, therefore, more elastic than lead and does not squeeze out of the joint as does lead in the case of settlement or repeated jars to the pipe. It is especially adapted in the case of pipe being laid on a curve as it will not blow out of such a joint on that part of the joint which is on the outside of the curve and is not driven in by caulking as happens so often with lead on that part of the joint which is on the inside of the curve.

Leadite is particularly serviceable in making repairs for the reason that it is easily handled being much lighter than lead. It is superior to lead in the case of a wet joint and when the joint has been run, the water can be turned on immediately without having to wait for the joint to be caulked.

During the past fall, the writer laid a line of 12-inch, 10-inch and 8-inch pipe nearly 5 miles long. The joints were run by an experienced man and the pipe was tested before the trench was backfilled and there was not a single leaky joint on the whole line and there has not been a joint leak on that line to date.

There have been two cases where sidehill slips carried small lines of pipe with them. In both cases, the leadite merely crushed in the joint causing a small leak, whereas, the writer's experience has been that lead, in such cases, would have partly or entirely blown out increasing the danger from the slip and the probability of claims for damages.

In making joints with leadite, the writer uses a little more than is given by the table published by the Leadite Company. This is because of the high pressures above referred to. Probably with lower pressures smaller amounts could safely be used. The table given below shows the average weight per joint of lead and leadite which is used and the cost per joint, the lead being computed at 5 cents per pound and the leadite at 10 cents per pound. The last column gives the saving per joint in material only. In addition to this saving there is the saving in excavation of large manholes for caulking in sizes from 12 inchs up, the saving of the cost of caulking and the added saving in the cost of maintaining the bell hole during the time that the joint is being caulked. There is also a saving in the cost of inspecting the caulking and a further item of saving in the cost of repairing an occasional lead joint even after it has been inspected. The leadite is much lighter in weight than lead which makes it easier to handle, it being possible to carry enough in one ladle to pour a large joint. This insures a better joint than with the case of lead, where the pouring is stopped for an instant after the first ladle is emptied.

The writer can give no figures on the saving of the items mentioned, but estimates that the total saving in the use of leadite over lead amounts to from half to two-thirds of the cost of lead joints, to say nothing of the obvious advantages of leadite over lead as a material for making joints.

Leadite is furnished in the form of a black powder, the base of which is sulphur. It melts at a temperature of about 240° F. and is therefore safer to use in a wet joint than lead. When first melted, there is considerable froth and scum formed on the surface of the liquid, but as the temperature rises, this passes off. As it is being melted it should be stirred continuously. If it is heated to too high a temperature, the leadite thickens into a pasty mass which cannot be run into a joint. When this happens the kettle should be removed from the fire or the fire from the kettle and with constant stirring the temperature is soon reduced and the leadite again becomes a fluid resembling a thin, black oil. It is then in condition to pour. It is probably a safe practice to heat the leadite until it assumes the pasty condition and then allow it to cool, as it is then always in condition to run and make a good joint. In running a joint it is necessary to provide a gate from 4 to 6 inches higher than the top of the bell in order to give sufficient head to fill the top of the joint. This for the reason that leadite is so much lighter than lead. If leadite is put into a hot kettle or is allowed to get too hot, the sulphur may ignite. The fire is easily put out, however, by throwing on a few handfuls of fresh leadite or a bucket of water if desired. No explosion will follow as the temperature of the leadite is not high enough to generate steam.

Table Showing Comparative Costs of Lead and Leadite for Making Joints in Cast Iron Water Pipe

SIZE OF PIPE INTERNAL DIAMETER	WEIGHT REQUIRED PER JOINT		COST		SAVING LEADITE OVER LEAD PER JOINT
	Lead	Leadite	Lead account 5 cents per pound	Leadite account 10 cents per pound	
inches	*pounds*	*pounds*			
4	7.0	2	$0.35	$0.20	$0.15
6	10.0	3	0.50	0.30	0.20
8	13.0	4	0.65	0.40	0.25
10	16.5	5	0.825	0.50	0.325
12	20.5	6	1.025	0.60	0.425
16	29.0	8	1.45	0.80	0.65
20	38.0	10	1.90	1.00	0.90

Leadite has a further advantage over lead in that it is a non-conductor of electricity. The writer has recently made tests to determine the relative conductivity of the two materials. Three lengths of 6-inch cast iron pipe were laid with lead and three others with leadite. A current of twelve volts was applied in each case. The three lengths with two lead joints showed no resistance, the whole twelve volts being registered by the volt meter, whereas, the three lengths with two leadite joints reduced the current to 2.4 volts. In making these experiments, however, it was found that the material of which the joint was made, whether lead, leadite or only yarn, made no difference in the conductivity of the pipe line if there was a contact of metal between the bell and spigot ends of the pipes. If, however, the pipes were insulated one from the other, the conductivity of the lead joints was very much more than that of the leadite joints.

Mr. Jordan: At Indianapolis we made what we thought was a very careful test of leadite, some upon a 30-inch conduit line on which there was practically no pressure. As far as we have been able to ascertain with regard to the few joints on which we used it there, they are holding out fairly well; we tested it also on a 6-inch line 700 feet in length, which was laid under the supervision of our engineers and our best pipe men as we wished to give the leadite a very careful test. We had all of the various literature that the leadite people have sent out, and we gave the material what we thought was a very fair trial. Within two hours after the line was in we turned on the pressure, only a small amount at first. A few leaks appeared, and on the following morning our chief engineer, Mr. Hurd, and myself went out there, and I believe we found in the entire line some three or four joints which were not leaking, but all the rest of them were working over time. Our experience on that was unsatisfactory. We regretted it very much, as we believed that we had found something which would do away with the necessity of educating caulkers and having them leave you just about the time their education was finished.

A Member: It seems that the great difficulty in the handling of this leadite is in the manner of preparing it. From what the writer says they must have had no trouble whatever in preparing this material, and I should say they must have had a good set of men and a good fireman to take care of the kettle.

MR. REIMER: In our case we had the assistance of men sent out by the Leadite Company the first time we used this material. The first case was that of a 6-inch main designed to carry about 75 pounds pressure. Our men did only as directed by the men sent by the Leadite Company, these latter men doing most of the work. When the water was turned on we found that out of 36 joints laid more than 20 of them leaked. We were assured by the Leadite Company that these leaks would take up, so as we were in a position to leave the trench open we watched these leaks for several days and then covered the line before the leakage had stopped. The leadite people assured us that our men would soon become proficient and be able to do better work than their own men and though we did not see how that could be we experimented once more, doing all of the work ourselves. This second experiment was on a 6-inch line designed to carry 100 pounds pressure and we certainly did get better results doing the work with our own men. Out of some 40 joints only 10 or 12 leaked.

We observed the leaks in these lines for about a year, occasionally opening the roads at the points of worst leakage and found that the leakage had decreased somewhat but not entirely in the case of the first line and had apparently stopped in the second case. Whether such an experiment can be relied upon for all cases is something that I do not know and would be glad if others who have had similar experiences would state whether such leaks have taken up in the course of time. We are not entirely discouraged by the experiences we have had and intend to do a little more experimenting with leadite to ascertain whether we will have any chance for success, for I think we all agree that lead is an expensive luxury when it comes to laying pipe lines, when the cost of labor, time of caulking and cost of material are considered. I understand that Mr. Hawley of the Pittsburg district is using great quantities of this material.

MR. JAEGER: I have some figures here that I will give to the convention for what they are worth. We have used leadite for about seven years. We have 45 miles of pipe laid with lead joints, and 20 miles laid with leadite. The lead lines were laid prior to 1902; the leadite lines were laid mainly in 1906 and 1907. The following shows the respective number of leaking joints of each material for the years given:

YEAR	LEAKING LEAD JOINTS	LEAKING LEADITE JOINTS
1907	18	22
1908	19	43
1909	17	18
1910	14	15
Total	68	98

The pressure varied from 75 pounds to 115 pounds. We laid a new line of 2500 feet of 8-inch pipe with leadite in a macadamized street at a total cost of 82 cents per foot including everything. The leadite averaged about 4½ pounds per joint.

I found it necessary to have experienced men operate leadite. We have to pour all the joints when the leadite is just right; if you pour too hot, or too cold, you will have trouble every time. I have found that leaks will take up over night, from the size of a straw to almost as large as a lead pencil, depending upon the amount of the leadite that you use in the joint.

MR. REIMER: We understood from the leadite people that some settlement could occur without destroying the value of the joints, but they certainly did not use the question of elasticity as one of their strong talking points for this material and from other remarks I take it that leadite is in no wise superior to lead from the standpoint of elasticity of joints. Certainly the material is brittle as cast in the joints, as anyone will say who has had experience in cutting out leadite joints.

MR. WESTON: I think I heard Mr. Hawley say at a meeting of the New England Water Works Association that he had used leadite for a pipe line crossing a marsh where the pipe had settled; the results were not entirely satisfactory.

MR. METCALF: Just to add a little to the diversity of opinion I can say that I have had one experience with leadite at Concord, Mass., where we used it very successfully on a line from the reservoir, not under great pressure, coming down into the town. The maximum pressure may have been 35 to 40 pounds. It resulted in a marked saving, because the trench was very wet and lay below the ground water level the greater part of the way.

I have been very much puzzled by the diversity of experience in the use of leadite.

The use of leadite by the Pennsylvania Water Company at Wilkinsburg has undoubtedly been very successful, and has undoubtedly resulted in a marked saving in the laying of the pipe. The limited experience that we have had has indicated about the same saving. Of course whether the joints will continue to be satisfactory for a long period of years we do not yet know. The experience is limited, as I remember it, to about eight or ten years; but there have been some very satisfactory results in the use of leadite.

There are two or three precautions which we found on our work were necessary, and to which Mr. Hawley has alluded, namely, that the gate must be high, 4-inch to 6-inch, in order to give a pressure on the leadite and make it fill the upper part of the joint. In the second place, the gate or funnel must be large enough so that it shall not chill the leadite and so reduce the flow that it will not fill the upper part of the joint, because you will notice that the surface of the leadite as it cools dips down in the form of an inverted cone, showing a shrinkage as the joint solidifies. By the observance of these precautions one can do good work. In one or two cases where the experience had been adverse I believe that failure to recognize this necessity was the cause of the trouble.

I was somewhat chagrined, I confess, by the experience at Indianapolis, because I believe that the trial of leadite was made there as the result of some things that I had related of experience elsewhere with it. I think that Mr. Hurd and Mr. Jordan gave it as fair a trial as they knew how to give it, and you have heard their verdict. Now, there you are. Two competent, honest men have had diametrically opposite experience with the material, after most careful trial.

As to the elasticity, Mr. Chairman I think it might be that Mr. Hawley had in mind the fact that when the lead is squeezed out of a joint there is no return. It is pudgy as putty would be.

MR. DIVEN: I spoke of that because I thought possibly it was a typographical error. I supposed that leadite was very inelastic.

MR. METCALF: It is true that it is brittle.

MR. DIVEN: It is spoken of as a non-conductor of electricity. Would not that cause the electricity to jump across the joints, and cause more electrolytic action than a continuous flow?

Mr. Earl: It seems to me that the experience of the gas companies ought to settle that point. A great many of them are now laying their joints in cement. I am rather inclined to think that they are not having the trouble with electrolysis that water companies are. I would like to know something about that. It is too late for us to dig up all of our lead joints and put in leadite on 515 miles of main at New Orleans; but if it would have reduced electrolysis to use leadite the failure to use it is one of the things that we can now only regret, because our electrolysis problem is very serious, something like $15,000 worth of repairs in the last year.

Mr. Worrell: Two or three years ago Mr. R. N. Ellis of Jacksonville gave us an interesting account of his experience with leadite. It developed in his case that when it was unsatisfactory it was because of the lack of skill of the man who manipulated the furnace; so he advised the use of a gasoline furnace whereby a uniform heat could be maintained. I expect to use leadite during this year, and whatever experience I have with it will be available to the association at its next meeting.

Mr. Gwinn: Three years ago we put in 500 feet of 6-inch pipe with leadite. At the end of two years after laying we dug up the pipe, examined the joints, and found them in good shape. I think that some difficulty has been experienced because of men not being familiar with the proper way of melting the leadite.

We had occasion to take out a leadite joint and we found it very difficult.

Mr. Diven: It melts so easily that I think it would be easy to melt it out.

Mr. Gwinn: We did not try that. I think if we had applied a torch it could have been gotten out more easily; but it has given very good satisfaction.

Mr. Weston: At one time I made an analytical investigation of this material, and from my experience with it I found that it was necessary to use the same precautions that one would employ in making a sand and sulphur joint. If I remember correctly the "leadite" is practically a sand and sulphur compound. It is composed of sulphur, finely powdered silicious material, and some iron. Naturally when

heated too hot it takes fire, and that is what should be guarded against in using it. Sulphur burns with a pale blue flame which in bright sunshine is hardly visible, and before one is aware the sulphur has burned away, and then the compound will not have sulphur enough remaining in it to make a good joint.

Mr. Shaw: I had occasion to lay about 2000 feet of 20-inch pipe last year, and after considerable correspondence with the leadite people they agreed to and did send Mr. McCabe to run the joints, and demonstrate the use of the leadite. We laid some 700 feet. The leadite was run entirely by Mr. McCabe, with a lot of men under his supervision. He had a 6-inch connection with a distribution system. There was more or less seepage at each joint. I tapped in and outside of the 6-inch gate put a 5-inch meter, shut the gate, and measured the leakage. We could not see from our observation that it took up any. At the end of three days the leakage per foot per joint at the first joint was 1.2 gallon per hour per foot of joint. At the end of the three day period it averaged between 1.35 and 1.5, apparently a little more leakage than at the beginning of the period. After more or less correspondence and another visit from Mr. McCabe we finally concluded to run the joints with lead and cut out the leadite. I thought they had had all the chance in the world to demonstrate what the stuff would do and how it would work. The statement was made that possibly the men in the employ of the water department objected to the use of leadite on account of its putting some of the caulkers out of business. Another reason for its failure may have been through the use of the gasoline or kerosene lead kettle. The leadite was run into the joints with a spigot, and we thought possibly if it had been ladled out and poured in the results would have been different; but we ran some of the 6-inch joints with a ladle, and there was no difference between those and the others. I had fully intended to use leadite if it proved satisfactory.

Mr. Dunham: If leadite contains a considerable percentage of sulphur should a question be raised as to its effect upon the iron after a long interval?

Many engineers dislike to use sulphur under machinery although the castings may be very thick and heavy. They fear the sulphur may in time affect the metal.

The joints in a water pipe would be far more susceptible of injury. It is yearly becoming apparent that the average cast iron pipe joint made with lead is a long period affair.

Mr. Ellis: I think I was among the first of those belonging to this Association to test and use leadite for making joints in cast iron water pipe. We first laid about ½ mile of 6-inch pipe using leadite for joints, when tested the joints were tight, with one or two exceptions these took up so that they leaked very slightly, at the expiration of one year we uncovered and examined the most of these joints, finding them in good condition and tight, we then laid some 6 miles of main varying in size from 6-inch to 12-inch, using leadite in the joints, the most of these joints are in good shape today, about this time we changed foremen and lost the men we had first instructed and who had jointed most of the pipe, the new men were as carefully instructed as the old ones, we laid 7 more lines of mains with leadite, one of them a 12-inch main on Bay street, now a part of the high pressure system, the joints on this main were rather close being from ¼-inch to ⅜-inch, special care was taken in running these joints as we knew they would be subjected to 180 pounds pressure when taken into the high pressure fire system; while under domestic pressure we had a number of leaks in this, and some of the other mains previously laid; after our high pressure pumps were put in this main was attached to the high pressure system and subjected to 180 pounds pressure, so many of these joints blew out in places that we cut out all the leadite and re-run the joints with lead, we also cut out the joints in an 8-inch main that gave us trouble and made lead joints, this experience made us stop using leadite generally, we had laid another mile of 6-inch pipe watching the joints closely to try and insure good joints, but many joints in this line leaked and being in doubt as to whether it was the men, the material or the method of handling we have stopped using leadite.

In melting the leadite we found that a slow fire was the best, as with gasoline or pitch pine wood there was danger of overheating, dry chips made the best material for an even heat. Our mains are under a domestic pressure of 60 pounds and for fire 110 pounds is carried. On the high pressure system 120 to 180 pounds is carried.

Mr. Albert Blauvelt: Am skeptical about this, also about the following question, No. 15.

Mr. C. Faller: Used a little, did not like it, most of the joints leaked.

Mr. H. G. H. Nutting: Tried small sample, and was not satisfied with it. Requires too accurate heating and results not sure.

MR. ARTHUR N. FRENCH: We have tested leadite, but have made no use of it. In test we found it difficult to heat and pour. Our engineer advised against its use, for the reason that its composition is about the same as the old "rust joint." A test joint which we had lying about the shop for a couple of years, certainly rusted considerably in the joint.

MR. C. FALLER: Leadite may be all right, but do not think that we can afford for the small difference in cost to have the feeling that we do not know just how the joints are doing.

MR. H. G. H. NUTTING: Cannot depend on men doing the work right. It might be possible to train a gang into getting good result with leadite.

Is it good practice for the meter reader to furnish the metered consumer with a statement of the quantity used? Would there not be less error by referring the consumer to the office for information?

MR. REIMER: We have met the situation in this way in East Orange. We have recently got out a four page pamphlet describing how meters should be read. These pamphlets have been distributed to all metered consumers, and the instructions are so plain that we believe every one will understand thoroughly the system of reading explained. We have in the pamphlet suggested that each consumer prepare a little card for preserving the meter reading so that he may from time to time keep track of the amount of his consumption. We have adopted the method of warning consumers in cases of extra heavy consumption. We are anxious to prevent large consumption by inducing the consumers to read their own meters at periods when we do not read them so that they will know just how much water is passing through the meter. We believe we are going to receive a great benefit from that system.

MR. ALBERT BLAUVELT: If the consumer does not know how to read the meter, let him get his information from the office, not from any of its subordinates.

MR. A. E. WALDEN: We do not allow our meter readers to give the consumer any information whatever as the consumer must apply at the office for this. It is not good practice to allow the meter reader to do this.

Mr. C. Faller: It is not good practice to refuse the consumers any knowledge he should have—trust them and they will trust you.

Mr. F. S. Shields: It is not compulsory on the part of our meter readers to give information, either on cards or orally, but meter readers are instructed to always notify the consumers if their consumption is large or excessive that they may immediately take steps to look for leaks and correct the trouble. The meter reader also willingly gives the reading to any party desiring it.

Mr. R. L. Peeler: Yes, believe in taking your consumers into your confidence, and publicity as to his consumption.

Mr. H. G. H. Nutting: We leave a duplicate, showing the mark on the dials. All other information must be obtained at the office.

Mr. Edward L. Hatch: No, the consumer should be told to apply at the office.

Mr. Ernest McCullough: It is a question of the allowance made for clerical help in the water department. If there is sufficient appropriation I think it is well to give the metered consumer a statement of the quantity of water used.

Mr. Arthur N. French: It depends upon the reader. In our case, we have one reader, and we feel safe in allowing him to give readings to water takers.

In your experience are fire services tapped for wrongful uses of water by the consumer without the consent or knowledge of the water department?

Mr. Albert Blauvelt: Undoubtedly at times, and by methods which deceive the insurance inspector at the same time.

Mr. F. S. Shields: We fortunately have had no such experience so far inspection has not shown that the fire service seals have ever been broken. Our rules are quite stringent, and violations of other rules have been followed by prosecution and punishment.

Mr. Edward L. Hatch: They are used for wrongful uses unless they are metered. We require that all fire lines be metered at the

expense of the owner, but do not make a charge for the water used at a fire, and have no yearly charge for the connection.

MR. ERNEST MCCULLOUGH: In my experience I have come across a number of instances in five different cities in which consumers tapped city mains without the knowledge or consent of the authorities, stealing the water. I am not at liberty to give further details but the facts are capable of verification. I have heard rumors of other cases.

MR. ARTHUR N. FRENCH: They certainly are. In one case we saved about 200,000 gallons per day, by the attachment of a meter, although the company repeatedly stated that it was not using any water except what it paid for. Another concern which was not supposed to use any water whatever, and only paid for fire pressure, developed meter readings of 3000 feet per day.

Does it pay to have stems of valves in the pipe system made of bronze and the stuffing box glands bushed with brass?

MR. ALBERT BLAUVELT: Yes the metal should be dissimilar and reduce the corrosion bond.

MR. C. FALLER: Yes.

MR. H. G. H. NUTTING: Yes! The quality is remembered long after the price is forgotten.

Is the steam turbine direct connected pump a success?

MR. A. E. WALDEN: The writer has recently been investigating the turbine pump, and there is no question as to the results obtained from such a pump direct connected to steam turbine.

MR. EDWARD D. DREYFUS (Commercial Engineer, with the Westinghouse Machine Company): From a purely mechanical standpoint the direct-connected turbine-driven pump has proven very successful and desirable owing to its maximum simplicity and minimum maintenance and attention. This fact has been fully demonstrated by the

large number of such outfits employed as auxiliaries in condenser and boiler feed work.

The efficiency of the direct-connected unit may not compare favorably with the high-duty pumping engine on account of the necessary sacrifices in the design of both the turbine and pump in the selection of a common speed. As the ultimate commercial economy does not hinge upon the unit efficiency alone, it becomes evident that for cases of long standby and emergency operation, it would prove to be the most attractive type. Several installations, somewhat of this nature and involving large power, have already been made.

Considering constant pumping service, requiring large units, better performance is possible with the interpolation of a reliable Reduction Gear of 98 per cent, or greater efficiency. Progress has already been made in this direction, and it should place the turbine-propelled set on a plane about the same as that of the high-duty reciprocating engine when maintenance is borne in mind.

What is the percentage of under-registration on water meters under ordinary service conditions?

Mr. Edward L. Hatch: Very little if they are taken out and tested every few years. We take out our five-eights meters after they have run 100,000 cubic feet and clean them and test, and find that with this care there is very little loss of registration.

Mr. Arthur N. French: We have not tabulated this matter, but always find when meters are several years old a good percentage of under registration.

Secretary Diven: Fur further discussion on this question see the discussion on the paper on water rates, by Mr. Earl.

In case of a large waste of water through poor plumbing, what has been found the most satisfactory way of adjusting the bill? In other words, should any reduction be made for special classes of waste, provided they are promptly attended to when notified by the Department, and if so, what rules governing such cases have been found most satisfactory?

SECRETARY DIVEN: I presume that question applies more particularly to metered systems. I suppose what it is desired to know is whether you are going to make the consumer pay for the leakage, or rebate it to him because the water wasted has not done him any good. It seems to me that would be mighty poor policy.

MR. THOMAS: In Massachusetts when they have a leak underground and the water is wasted without any benefit to the consumer, and without his possible knowledge, a rebate is made. The average amount for the last four quarters is ascertained, and this compared with the total meter reading shows the excess wasted. This excess is divided in half, the consumer paying one-half and the water works bearing the other half. That is quite generally the custom.

MR. DIVEN: If the consumer did not have to bear any portion of the cost there would be no inducement to him to report or repair the leak.

MR. CRAMER: When ever there is any complaint of a leak in our city we send out an inspector, and if the leak is our fault we stand it. If it is something that could have been prevented by the water taker we deduct the average bill from the amount of bill in question, and then divide the remainder. So the consumer stands one-half of the excess, and the company stands the other half.

MR. E. E. DAVIS: We leave a notice with the consumer showing the excess bill, and the consumer has to look after the repairs and furnish our office a statement from the plumber who did the repairing, and then our inspector verifies the statement, and if the leak was under ground or where it could not be seen, the consumer has to pay for the waste at the minimum rate, and is rebated the difference between the minimum charge of 5 cents a thousand and the amount that he paid. We make him pay at the lowest rate we have.

MR. WORRELL: At Meridian, Miss., we get at this in practically the same way as does Mr. Thomas, at Lowell, Mass., and Mr. Cramer at Lexington, Ky., though we have a different method of making the adjustment. For instance, (we allow a cash discount of 25 per cent for payment within ten days after the bills fall due—the rates being loaded to bear it)—if the reading shows a heavy usage an inspector visits the premises for the purpose of locating the trouble. Should it

be found to exist in a leak where the consumer was not liable to find it we make a further discount of 25 per cent and adjust the bill on that basis, provided the bill amounts to four or five times what it ordinarily is. My personal opinion of the matter is different, however, as I think every man should pay for the amount consumed, if he is able to do so, and if he is not able then it should be given to him by the company or department rendering the service, and charged to "Incidentals."

Secretary Diven: I do not see why any reduction should be made; it costs as much to pump and filter water wasted as it does the water used.

Is the customary method of "hammer testing" cast-rion pipe while under 300 pounds or greater pressure in the press, in the best interests of the pipe or the purchaser? In the smaller sizes and lighter weights of pipe, will not a sharp blow of the sized hammer generally used for such test, in the hands of an "energetic" tester, produce a crystallization of the metal that might be the primary cause of weakness or rupture when the pipe is under strain from severe "water hammer?"

Mr. Milne: We have done a little experimental work along that line since the last convention, which drew my attention to a peculiar fracture of a light weight 4-inch pipe. A microscopic examination of the pipe disclosed complete crystallization from the exterior to the interior of the pipe. I took the matter up with a couple of engineers that we employ to do pipe testing there in Canada. One of them had made rather an extended examination, both microscopical and otherwise, covering a series of tests of pipe that were culled in the shop for that purpose. I believe he has some data that he would have submitted had he been able to get here, which unfortunately he was not able to do.

The question of hammer testing is one that has long appealed to me and I have been particularly interested in watching the testing operation at the foundry. While the specifications of the American Society of Testing Materials call for the use of a wooden hammer, I have never yet seen a wooden hammer used at a foundry in making such tests, but they use about the same kind of a hammer as a railroad inspector does in testing car wheels unless somebody compels him to do otherwise. You will find some muscular athlete just out from

college occasionally trying to make good in the testing, using a 16-ounce hard steel hammer, with perhaps a 16-inch handle; with the result that he will hit the pipe a fairly good crack; and if the pipe should be slightly hard the results may not be the best. I think that better results in inspection of pipe would be obtained by the use of a hammer of wood or of copper or of other soft metal of an equivalent weight, which would produce the necessary vibratory movement in the structure of a pipe without inducing any subsequent weakness or rupture, or any detrimental effects in the form of crystallization such as would be produced by a too hard tool when used too energetically. My sole object of investigating was to gain information upon that point, and not having in view answering this question.

MR. E. E. DAVIS: I made a test myself of a 12-inch pipe $\frac{7}{16}$ inch thick. We put 300 pounds on it, and struck it with a half pound hammer with a 12-inch handle. The man who made the pipe said it would not stand any more pressure than that, but I put on the pressure up to 500 pounds and gave it the same hammer test, and the pipe stood the test all right.

Are streets in your city sprinkled by the street car company?

MR. MILNE: I know of a number of cases where they do the sprinkling. In some of these cases the sprinkling is required in the franchise and is a part of the franchise agreement. I might obtain more data and send it in in writing.

MR. CAULFIELD: In our city an ordinance having been passed requiring the street car company to sprinkle, they refused to do it, and the matter went to the courts, which decided that it had to sprinkle. The question arose as to whether the water department would have to furnish water free to the street car company to do the sprinkling; and the city attorney decided that the street car company must make their own arrangements for water, that the water department was not compelled to furnish it ot them free. There are a number of street car companies in the United States that sprinkle streets.

MR. E. E. DAVIS: The street car company's franchise in Richmond requires them to sprinkle their tracks, and for this purpose the city gives them water free.

MR. CAULFIELD: The decision of the court in our case was based on the question of public health, it decided that the street car company created a great deal of dust, and the court's ruling was that it had to protect the people's health.

SUBJECT INDEX

Alkalinity, 8 p. p. m. necessary to prevent corrosion 288
effect on corrosion of iron 260
should not be less than 10 to avoid hot water troubles 278
Alum, use of increases carbonic acid in water 260
use of with soft colored water should be avoided 278
compounds in filtered water 267
Alum, treated water, effect of heat on 267
Alvord, John W., discussion on return for fire hydrant service 145
discussion on water rates 189
Application of hypochlorite, discussion by A. E. Walden 442
Area, better index of hydrant efficiency than linear spacing 110
proper for hydrant to serve 110
Ashland, Wis., per cent of cost of works necessary for fire demands 63
Atlanta, Ga., effect of cleaning force main at 41
Automatic sprinklers, quantity of water used by, to extinguish fires 56
Bartow, Edward, discussion on purification of drinking water 314
Bass, Frederick H., discussion on emergency intakes 154
discussion on purification of drinking water 315
Bemis, Edward W., discussion on water rates 195
Berry, J. P., discussion on hot water problems 290
Bettes, Charles R., effect of cleaning on cast iron pipe 49
Blauvelt, Albert, discussion on fire line meters 23
discussion on question of water softening 426
discussion on return for hydrant service 141
Bleach, character of waters governing quantity to use 314
emergency plant for application of in Minnesota 315
Boilers, at Milwaukee pumping station 31
Booth, George W., chief engineer National Board Fire Underwriters, on fire prevention 109
comment by on water required for fire fighting 75
discussion on return for hydrant service 143
Booth, William Miller, answer to question on water softening 425
Brown, Charles Carroll, paper by, Method of Keeping Records of Improvements to establish Water Works Plant 317
Brown, I. B., discussion on return for hydrant service 133
discussion on water rates 203
Butler, Pa., use of emergency intake at 152
Calcutta water works 355
raised reservoir or tank 355
reservoir foundation, ... 357
the tank or reservoir 359
roof of tank or reservoir, ... 360
steel structure supporting reservoir 359

Carbondale, Ill., effect of cleaning water mains at 41
Carbonic acid, rôle of in hot water troubles 260
Cast iron, resistance to corrosion due to silicious received in mould 226
Cast iron pipe, breaks greater proportionately in large size 221
effect of cleaning on useful life of 45
cost increasing with size 223
damage to by long shipments 163
effect of soil on 46
loss of iron, in due to corrosion 46
records of age of 226
Caulfield, John, discussion on fire line meters 10
Centralia, Ill., increased efficiency by cleaning water mains 45
Chester, J. N., discussion by, on fire line meters 5
discussion on fire line meters 13
discussion on hot water problems 285-289
discussion on pumping station management 35
discussion on return for hydrant service 130
discussion on water rates 198
Chlorine, bearing on sanitary quality of water 294
Check valves, multiplicity on fire lines bad 7
Cleaning pipe, effect on useful life of cast iron 45
Cleaning water mains, corrosion more rapid than before 48
effect of 40
effect on economy of operation 41
increase in investment due to 46
Coal, handling of at Milwaukee pumping station 29
Pocahontas compared with Youghiogheny 37
use of Pocahontas at Milwaukee 37
Color, effect on salts in solution on 263
Compressed air in water works construction, ... 339
Coöperation between water and insurance interests, advisability of 17
Copper clad bands for wood stave pipe in salt marsh 166
Corrosion, cause of corrosive action of hard waters 290
effect of alkalinity of water on 260
effect of soils of high organic content, on 226
same electrolytic theory of 243
little difference between wrought iron and steel pipes 274
modern and generally accepted theory of 243
oxygen conditions for 270
theory of 242
what neccessary in water for 243
more rapid after cleaning cast iron mains 48
of water mains not equally distributed through distribution system. 52
Coventry, H. G., paper by, Stripping Reservoir Sites at Newcastle, Eng. 367
Current meters, area of propellers in 3
compared with detector meters 3
Davis, E. E., discussion on fire line meters 20
discussion on hot water problems 291

Deposit in mains, effect on carrying capacity 39
Depth to lay main, discussion on question by Edward L. Hatch,. ... 436
discussion on question by Ernest McCullough 436
discussion on question by H. G. H. Nutting 436
Detector meters, compared with current for fire services 3
Distributing systems, restoration of old, Hodgman 39
Distribution system, proportion chargeable to fire protection service 63
Diven, J. M., discussion on fire line meters 22
discussion on hot water problems 279
discussion on wood stave pipe 170
Dunham, H. F., discussion on restoration of old distributing systems 47
discussion on return for hydrant service 147
discussion on steel vs. cast iron pipe 229
discussion on water rates 205
Duties of Pumping Engines, ... 36
Earl, George G., paper by, Water Rates 173
discussion on water works 213
Electrolysis, action of, on steel pipe 228
at Sydney, Australia 419
Emergency intake at Butler, Pa., ... 152
Emergency intake at Lowell, Mass 151
Emergency intake at Newark, N. J. 151
Emergency intake at Ottawa, Canada, ... 152
Emergency intakes, are they good policy 152
leakage of closed gate on 152
seal no protection 155
use of hypochlorite when used 154
discussion by Frederick H. Bass 154
discussion by Harry Ellsworth 154
discussion by M. Knowles 152
paper by Dr. William P. Mason 151
Far Rockaway, N. Y., effect of cleaning on cast iron pipe at 49
Filtration, mechanical does not always cause hot water troubles 256
Filtered water, alum compounds in 267
Finsen, Prof., first producer of ultra violet rays 341
Fire departments, per capita maintenance of 111
Fire engines, annual cost of maintenance of 114
capacity of 377
chemical 381
cost of 114
cost of maintenance of 110
dimensions of 372
per cent capacity delivered 114
portable compared with high pressure for fire service 369
pumps of 380
slippage in 376
too high speed of, not desirable 376
usual condition of 110
Fire hose, proper length to use 110

Fire hydrants, actual and desirable number ... 106
advantage and saving of in between ... 121
all should be at same price ... 131
annual adjustment of rental ... 116
area served best index of protection ... 110
area they should serve ... 110
area served by ... 108
average amount of distribution pipe to ... 113
average number per mile of pipe ... 106
charge for in excess of minimum number ... 109
charge per number of wrong ... 136
common method of paying rental for ... 116
cost of installing additional ... 114
cost of maintaining ... 121
cost to water company of increased number of ... 110
distribution of charges for ... 122
feet water pipe per hydrant ... 106
how proper spacing determined ... 110
how viewed by National Board Fire Underwriters ... 109
limitation in number of, undesirable ... 109
improper use of ... 136
necessity of expert study of, charges for ... 127
number per mile ... 113
number should not be basis for return for ... 126
number of streams from ... 110
offsetting taxes or franchises as rental undesirable ... 117
per capita cost of service ... 115
per capita cost equal $55 annual rental ... 115
points for examination for rentals ... 115
proper form of contract for ... 109
proper spacing of ... 109
proper number to block ... 110
proportion of construction cost ... 115
range for rental for ... 113
rates for should be adjusted periodically ... 127
reasonable return for, discussion on by M. Knowles ... 122
rental based on charge per hydrant detrimental ... 109
rental of as offset to taxation ... 111
rental of as offset to franchise value ... 112
rentals related to cost or value of service ... 113
rental usually based on averages ... 113
reduced insurance rates on account of ... 128
reduction on insurance rates necessary to maintain ... 121
spacing based on study of area served ... 113
statistic of rentals of ... 113
study of basis of charges for ... 127
suggested improvements in rental for ... 116
use and abuse of ... 135
usually paid for as rental per hydrant ... 112

Fire hydrant service, data regarding, in various cities 56
reasonable return for, discussion by F. C. Kimball 119
reasonable return for, discussion by Leonard Metcalf 117
need of inquiring into number of nozzles as well as hydrants 95
per capita cost of 93
relation between per capita cost of and cost per hydrant 94
Fire insurance, average charge for in states 102
effect of development of water works on rates 103
effect on rates of establishment of municipal water works 104
failure to reduce rates for, after water works established 104
per capita saving account rate reduction 105
ratio of value of property 103
rates lowest in densely populated states 102
reduction in rates by construction of water works 104
reduction in rates by establishment of efficient water works 25 per cent 105
Fire line, obstruction of at Springfield, Mass 18
tampering with sealed valve on 21
Fire lines, danger of strainers on 8
effect of profits by wrongful use of water from 17
inefficiency of seals to protect from wrongful use 21
meters on tested by insurance interests 9
necessity of meters on 18
should be isolated from other supplies 5
shutting of account non-payment of water bill 21
use of meters on 21
wrongful use of water from, at Kalamazoo, Mich 14
Fire line connections, size for 8
Fire line meters 1
discussion on, by Albert Blauvelt 22
discussion on, by Caulfield 10
discussion on by Chester 5
discussion on, by Chester 13
discussion on, by Diven 22
discussion on, by Griswold 5
discussion on, by Griswold 9
discussion on, by Hawley 16
discussion on, by Houston 13
discussion on, by Houston 6
discussion on by N. S. Hill, Jr 17
discussion on, by Watson 11
no one make approved by insurance interests 9
Fire loss, effect of water works on 104
Fire losses, may be a benefit 131
on property owners as a class not on insurance companies 129
Fire losses in Greater New York 101
Fire prevention, George W. Booth, Chief Engineer National Board Fire Underwriters, on 109
views of engineers, National Board Fire Underwriters on 109

Fire protection, basis of payment for 126
city water not necessary for 25
cost of 151
cost of furnishing 66
cost of, relative to other service 116
destructive to human life 151
effect on insurance rates 120
effect of payment for, on taxes 111
estimate of cost of 83
growth in demand for independent high pressure systems for 91
extra charge account private ownership waterworks 135
inequity of including charge for in water rates 138
insurance reduction on account of 115
loss by fire or death by typhoid 151
municipality should pay water department for 138
operating and maintenance charge for 92
per centage of total capacity of system required for 70
portion of capacity of pipe system chargeable to 76
proportion of total capacity of pipe system chargeable to 66
quantity of water necessary for 71
relative cost of 112
what does it cost to furnish 125
Fire protection service, value 95
Fire services, are they tapped for wrongful use of water 454
wrongful use of water from 454
Fire waste, per capita cost of 122
Fires, quantity of water to extinguish with automatic sprinklers 56
Fisher, E. A., discussion on hot water problems 286
Fisher, Hon. Walter L., Secretary of Interior, address before National Fire Protection Fire Association 122
Flushing, does not remove tubercules, ... 52
Free water, municipal works Madison, Wis., prohibited from supplying to other departments 124
Galvanized pipe, action of soft water on 274
Galvanizing, thoroughness of, controls corrosion 275
Ganz, Prof., water softening by Zeolith devised by 347
Gate valves, multiplicity of, on fire line objectionable 7
Griswold, F. M., discussion on fire line meters 5
discussion on fire line meters 9
Gwinn, Dow R., discussion on hot water problems 292
discussion on pumping station management 37
discussion on return for hydrant service 132
Hague, Charles A., paper by, High Pressure Fire Service Compared with Portable Fire Engines 369
Hammer testing, discussion by E. E. Davis 459
discussion by Alexander Milne, ... 458
cast iron pipe, is it good practice 458
Hatton, T. Chalkley, discussion on reasonable return for hydrant service 137

Hatton, T. Chalkley, discussion on wood stave pipe . . . 171-172
method of determining hydrant rental . . . 137
paper by, Wood Stave Pipe . . . 161
Hawley, W. C., discussion of fire line meters . . . 16
discussion on reasonable return for hydrant service . . . 55
discussion on reasonable return for hydrant service . . . 135
Hawley down draft furnaces at Milwaukee Pumping Station . . . 29
Hazen, Allen, paper by, Steel vs. Cast Iron Pipe . . . 217
Hemlock Lake, corrosion of steel conduit from . . . 227
Hering, Rudolph, discussion on hot water problems . . . 281
discussion on water rates . . . 210
High pressure fire service . . . 383
allowance for leakage in . . . 389
compared with portable fire engines, Charles A. Hague . . . 369
distribution of hydrants on . . . 389
fire losses saved by . . . 390
pumping machinery used in . . . 387
standard features of . . . 386
growth in demand for . . . 91
High pressure fire systems, what has led to introduction of . . . 114
Hill, Nicholas S., Jr., discussion on fire line meters . . . 17
discussion on steel, vs. cast iron pipe . . . 224
Hodgkins, H. C., discussion on water rates . . . 204
Hodgman, Burt B., paper by, The Restoration of Old Distributing Systems . . . 39
. . . 39
Holmes, William, discussion on water softening . . . 425
Hot Water, appartment house supplies . . . 235
cause of red water plague . . . 232
circulating system . . . 235
consumption of, depends on character of plumbing . . . 233
corrosive effects of . . . 242
effect of heating on quality . . . 241
materials of construction of systems . . . 214
materials used in systems . . . 254
methods of heating . . . 233
methods of supplying and distributing . . . 234
pressure system of supply . . . 234
quantity used . . . 232
red color not usually due to natural iron in water . . . 242
rusty water . . . 242
supply for tall buildings . . . 235
tank method of supply . . . 234
temperature required for domestic service . . . 232
Hot water problems, discussion by J. P. Berry . . . 290
discussion by J. N. Chester . . . 285-289
discussion by E. E. Davis . . . 291
discussion by J. M. Diven . . . 279
discussion by Dow R. Gwinn . . . 292
discussion by M. Speller . . . 283

Hot water problems, discussion by B. F. Stedman 291
discussion by Robert Spurr Weston 287
discussion by George C. Whipple 289
Hot water troubles, paper by George C. Whipple 231
alkalinity shoud not be less than 10 278
avoided by using brass pipes 277
color removal cause of 288
caused by unprotected steel tank 254
classification of water causing 244
difficulty of obtaining good iron or steel pipe 276
due largely to character of plumbing 281
effect on of thorough galvanizing 275
experiments in England to overcome 282
from water naturally charged with iron 257
greater with clear water 249
greatest in buildings of cheaper construction 274
increased by rapidity of circulation 273
more marked with pressure than with tank systems 259
effect of algae on 257
effect of material used in system on 259
roll of organic acids 260
from waters overdosed with alum 256
from soft colored waters 247
from soft ground waters 245
from water high in chlorides and low in carbonates 246
from soft waters treated with alum 248
greater in modern houses 258
greater with soft waters 259
greatest in winter 257
localization of 258
not always present with mechanically filtered water 256
not hygienic 231
prevented by increasing hydroxylions 277
prevented by reducing hydrogenions 277
reduced by reducing temperature 277
remedied by use of copper boilers and brass pipe 258
remedies for 277
role of carbonic acid 260
seasons of 257
steel pipe as cause of 274
temporary rustiness 259
temporary rustiness from different metals in gas heater 259
tests with various heating apparatus 281
unprotected steel tanks as cause of 274
use of aeration as remedy for 287
use of lime as preventative of 283
vary in different parts of house 259
Hot water troubles in Springfield, Mass. 253
Houston, George, paper by, Fire Line Meters 1

Houston, George, discussion on fire line meters 6
discussion on fire line meters 10
Hydrants, cost of installing extra 90
Hydrant rental, a standard method of assessing 65
bases for analysis of 65
by decades 61
position of railroad commission of Wisconsin concerning 62
proper method of paying 65
usual method of payment of 64
use of saving in insurance rates as base for rate for 106
Hydrant rentals in the United States, corporation owned plants 57
Hydrant spacing, George W. Booth on 110
Hypochlorite, experience in the application of 442
use of with emergency intakes 154
Ice, cause of stand pipe accidents 169
India, some water works experiences in 353
Indianapolis, hydrant rental in 134
Insurance interests, have not approved of any make of meter 9
Insurance, effect of unapproved meters on rate of 1
Insurance rates, failure to reduce account protection improvements 135
Interpretation of water analyses by Daniel D. Jackson 293
Investigation of underground water waste in Washington, D. C., W. A. McFarland 361
Iron pipe, influence of character on rusty water 274
Joint connections with fire lines, discussion on question of, by Albert Blauvelt 437
discussion on by J. M. Diven 438
discussion on by Arthur N. French 438
discussion by on E. C. Levy 437
Jordan, Frank C., discussion on a reasonable return for hydrant service 133
Kalamazoo, Mich., attitude of underwriters concerning meters on fire lines at 14
Kimball, Frank C., discussion on return for fire hydrant service 118
Knowles, Morris, discussion on emergency intakes 152
Knowles, Morris, discussion on return for hydrant service 122
Kuichling, Emil, reasonable return for fire hydrant service 55
Kunhardt, L. H., discussion on fire line meters 18
Lawton, R. W., paper by, Some Water Works Experiences in India 353
Leadite, cost of joints compared with lead 445
Leadite for Joints, discussion by Albert Blauvelt 452
discussion by J. M. Diven 449-450
discussion by H. F. Dunham 451
discussion by George G. Earl 450
discussion by Dow R. Gwinn 450
discussion by W. C. Hawley 443
discussion by R. N. Ellis 452
discussion by C. Faller 452-453
discussion by Arthur N. French 453
discussion by Frank C. Jordan 446

Leadite for Joints, discussion by Leonard Metcalf....448-450
discussion by H. G. H. Nutting....452-453
discussion by A. A. Reimer....447-448
discussion by Mr. Shaw.... 451
discussion by Robert Spurr Weston.... 448
discussion by M. L. Worrell.... 450
discussion by A. J Yeager.... 447
Leal, Dr John L., paper by, Purification of Drinking Water.... 299
Leisen, Theodore A., discussion on water rates.... 189
Leiber, Richard, Adjustment of hydrant rental and insurance rates at Indianapolis, by.... 134
Lockport, N. Y., first direct pressure fire service installed at.... 369
Louisville, Ky., report on meter rates.... 190
water for municipal purposes free.... 189
Lowell, Mass., use of emergency intake at.... 151
water failure on lock and canal system at.... 19
Machen, Henry B., discussion on pumping station management.... 38
Madison, Wis., municipal works prohibited from supplying free water to other departments.... 124
Mason, Dr. William P., paper by, Emergency Intakes.... 151
Massachusetts, fire insurance data.... 98
Maury, Dabney H., return for hydrant service.... 128
McFarland, W. A., paper by, Investigation of Underground Water Waste at Washington, D. C.... 361
McMillan, Thomas, paper by, Pumping Station Management in Milwaukee. 25
discussion on restoration of distribution systems.... 50
Metcalf, Leonard, Reasonable return for fire hydrant service.... 55
discussion on return for fire hydrant service.... 117
discussion on wood stave pipe.... 171
Meters, fire line.... 1
is it good policy to furnish statement to consumer.... 453
necessity of, on fire lines.... 18
under-registration of.... 456
under-registration discussion by Edward L. Hatch.... 456
of on fire lines.... 21
Meters on fire lines, effect on on pressure.... 9
Meter rates, report on at Louisville, Ky.... 190
Meter readings for consumers, discussion by Albert Blauvelt.... 453
discussion by C. Faller.... 454
discussion by Arthur N. French.... 454
discussion by Edward L. Hatch.... 454
discussion by Ernest McCullough.... 454
discussion by R. L. Peeler.... 454
discussion by H. G. H. Nutting.... 454
discussion by A. A. Reimer.... 453
discussion by F. S. Shields.... 454
discussion by A. E. Walden.... 453
Metering non-paying water takers, discussion by Albert Blauvelt.... 442
discussion by Arthur N. French.... 442

Metering non-paying water takers, discussion by F. S. Shields..... 442
discussion by John C. Trautwine, Jr.. 441
discussion by A. E. Walden 442
Methods of keeping records of improvements to establish water works plants, paper by Charles Carroll Brown..... 317
Milne, Alexander, paper by, Compressed Air in Water Works Construction.. 337
discussion on compressed air in water works construction.. 339
Milwaukee, description of pumping plant at.. 25
history of water supply of..... 26
operation North Point pumping station 34
type of boiler used at pumping station 31
pumping plant, feed water..... 31
Milwaukee pumping station, oiling system.. 33
management in..... 25
packing..... 33
Milwaukee specification for coal,..... 30
Minnesota, dangerous emergency intake in 154
Municipal water works, inequity of including fire protection in water rates..... 138
should be compensated for hydrant service..... 138
National Board of Fire Underwriters, does not deal with rates,..... 144
object of..... 143
report on water necessary for fire fighting in excess of domestic consumption..... 71
views of engineers on fire prevention..... 109
New Orleans, how water rates established at..... 178
New York, fire losses in greater..... 101
New York, insurance statistics of state of 101
Newark, N. J., use of emergency intake at 151
Oiling, system at Milwaukee pumping station..... 33
Organic acids, corrosive effect of, not known..... 261
Ottawa, Canada, use of emergency intake at..... 152
Oxygen, solubility of dissolved..... 271
Oxygen conditions, effect on corrosion 270
Packing pumps, Milwaukee pumping station. 33
Pipe, effect of cleaning on useful life of cast iron..... 45
experience with iron and steel at Rochester, N. Y..... 286
influence of character of iron and steel on rusty water 274
is custom of hammer testing good practice..... 458
Pittsburg, Pa., emergency intakes rejected at 153
Powell, S. T., paper by, Sterilization of Water by Ultra Violet Rays. 341
Power calking, description of apparatus for..... 439
discussion by Albert Blauvelt..... 439
discussion by A. E. Walden..... 437
experience with, at Baltimore, Md..... 439
time 12 inch joint..... 439
tools used for 440

Power driven trench pumps, discussion on saving by use of by Albert Blauvelt 431
discussion on saving by use of, by E. E. Davis 430–431
discussion on saving by use of, by A. N. French 431
discussion on saving by use of, by W. C. Hawley 429
discussion on saving by use of, by Ernest McCollough, ... 431
discussion on saving by use of, by H. G. H. Nutting, ... 431
discussion on saving by use of, by Albert H. Wehr 430
discussion on saving by use of, by Albert Spurr Weston 429–431
discussion on saving by use of, by C. W. Wiles, ... 430
Power driven trench pumps, is there economy or saving in use of 429
Pressure, reduction of by fire line meters 9
Private fire protection, provided for with public 124
Private fire service, city water supply not necessary for 142
city water used because cheaper 142
sources of supply for 142
Public service, cost of other than water 125
Public service commission Wisconsin, prohibited Madison water department supplying free water to other departments 124
Pumping engine duties 36
Pumping station employes,, promotion of 35
Pumping station management in Milwaukee, paper by Thomas McMillan 25
Pumping station management, discussion by J. N. Chester, ... 35
discussion by Dow R. Gwinn 37
discussion by Henry B. Machen 38
discussion by McMillan 37
discussion by Leonard Metcalf 37
Purification of drinking water, by John L. Leal 299
discussion by Edward Bartow 314
discussion by Frederick H. Bass 315
emergency use of bleach 312
portable sterilization plant for 314
processes of 302
rapid mechanical filtration with coagulation 305
results of use of bleach 309
sedimentation 302
slow sand filtration 303
sterilization or disinfection 307
Wisconsin emergency plant for 315
Question Box 425
Records of improvements, cash disbursement and voucher record 317
classification of 317
engineer's record of material and labor 320
special stock account 318
Red water, caused by corrosion of tanks and service pipes 242
Red water troubles, discussion on question of by Arthur N. French 437
discussion on question of, by H. G. H. Nutting, ... 437
discussion on question of, by F. S. Shields, ... 437
Restoration of old distributing systems, by Burt B. Hodgman, ... 39

Restoration of old distributing systems, discussion by H. F. Dunham ... 47
discussion by H. C. Hodgkins 49
discussion by Burt B. Hodgman 48
discussion by Charles C. Hopkins 49
discussion by Thomas McMillan 50
discussion by M. L. Worrell 50
Reasonable return for fire hydrant service, discussion by John W. Alvord 145
discussion by Albert Blauvelt 141
discussion by I. B. Brown 133
discussion by J. N. Chester 130
discussion by H. F. Dunham 147
discussion by Dow. R. Gwinn 132
discussion by T. C. Hatton 137
discussion by W. C. Hawley 135
discussion by F. C. Kimball 119
discussion by Morris Knowles 122
discussion by Dabney H. Maury 128
discussion by Leonard Metcalf 117
discussion by C. B. Salmon 138
Return for fire hydrant service, basis of 55
distribution of charges for 122
educational value to citizens of paper on 132
graduated rental 145
insufficient consideration given to loss and maintenance of hydrants 147
method of determining, Hatton 137
number of hydrants should not be basis for 126
periodic adjustment for 127
suggested new basis for 145
study of basis charges 127
Richmond, Va., connection between separate fire supply and city mains not allowed 22
meters required on fire lines at 20
Rochester, N. Y., experience with iron and steel pipe at 286
Rumford Falls, Maine, hot water troubles at 287
Salmon, C. B., discussion on return for hydrant service 138
Sherman, Richard U., discussion on water rates 206
Simin, Boris N., water softening by means of Zeolith 347
Smith, W. Z., discussion on restoration of distribution systems 52
Soft Water, action on galvanized pipe 274
Some fundamental considerations in the determination of a reasonable return for public fire hydrant service, Metcalf, Kuichling and Hawley 55
Some water works experiences in India by R. W. Lawson 353
Springfield, Mass., hot water troubles at 253
obstruction of fire line at 18
steel pipe used for river crossing at 223
Sprinkler system, brief description of 2
stoppage of part does not impair efficiency of balance, 8
Sprinkling streets by car company 459
discussion by John Caulfield 459-460

Sprinkling streets by car company, discussion by E. E. Davis..... 460
discussion by Alexander Milne..... 459
Stand pipe accident, A, by H. C. Hodgkins..... 157
Steam turbine, direct communicated pump, is it a success?..... 455
Steam turbine pump, discussion by Edward D. Dreyfus..... 455
discussion by A. E. Walden..... 455
Stedman, B. F., discussion on hot water problems..... 291
Steel, for pipe, date of..... 217
Steel pipe, breaks comparatively small in..... 222
concrete covered cost less than large sizes cast iron..... 224
corrosion more rapid in clay soils and marsh..... 227
corrosion not equally distributed..... 219
cost below cast iron equal to renewal cost..... 218
depreciation of..... 227
design not standardized..... 223
electrolysis more rapid in than in cast iron..... 227
expansion and contraction not serious..... 223
for greatest safety use soft steel..... 222
hardness of metal cause of breaks in..... 222
how perforation is caused..... 219
influence of character of on rusty water..... 274
leaks in grow rapidly..... 219
lock bar equivalent to cast iron in smoothness..... 222
oldest in America about twenty years old..... 219
ordinary limit of sizes of..... 223
perforations caused chemically..... 219
perforations caused mechanically..... 219
progress in manufacture of..... 288
salt water contributing cause of corrosion of..... 220
stronger and more reliable than cast iron..... 220
two principal patterns of..... 222
where it may be used..... 229
Steel vs. cast iron pipe, paper, by Allen Hazen..... 217
discussion by H. F. Dunham..... 229
discussion by Nicholas S. Hill, Jr..... 224
Sterilization of water by ultra violet rays by Walden and Powell..... 341
Strainers, danger of on fire line..... 8
Stripping reservoir sites at Newcastle, England, by H. G. Coventry..... 367
Sulphate alumina, amount required to reduce color and reduction in alkalinity..... 263
reaction in water containing calcium carbonate..... 267
Superintendent's salary, discussion on question of by Arthur N. French. 439
discussion on question of by Ernest McCollough..... 439
Sydney water supply, Its history and management by Charles W. Smith. 393
Sydney water supply, cost of works..... 419
distribution system..... 410
history of..... 394
management and maintenance..... 413
water analyses..... 413

Sydney water works, cost of pumping 119
Talbot, Prof., investigation of stress produced by fill on pipes 221
Tapping fire lines, measures taken by insurance interests to prevent 11
Thomas, R. J., discussion on fire line meters 19
Trash Catchers, effect of not using 2
meters objected to as 1
Trautwine, John C., Jr., paper by, Public Utilities 331
discussion on water rates 207
Ultra violet rays, as auxiliary to filtration 341
destruction of bacteria by instantaneous 344
first produced by Prof. Finsen 341
result of sterilization by 343
sterilization of water by 341
Underground water waste, difficulties encountered in investigation of 361
method of detecting in mains 364
method of investigation in Washington, D. C. 362
objection to long continued tests 362
protographic records unreliable 362
Underwriters, makes of meters consented to by 1
United States Geological Survey, estimate of cost of fire protection service 87
Use of oil for fuel, discussion on question by J. N. Chester 433
discussion on question by John R. Downs 435
discussion on question by F. L. Johnson 434
discussion on question by A. E. Walden 434
Valves, should stems and stuffing box glands be made of brass? 455
Valve stems of bronze, discussion by Albert Blauvelt 455
discussion by C. Faller 455
discussion by H. G. H. Nutting 455
Van Gilder, L., discussion on wood stave pipe 172
Walden, A. E., paper by, Sterilization of Water by Ultra Violet Rays 341
Walker, test for porosity of wrought iron pipe 55
Washing filters with well water, discussion on question of success of by John W. Alvord 432
discussion on question of success of, by J. N. Chester 432
discussion on question of success of, by J. M. Diven 432
discussion on question of success of, by William Holmes 433
discussion on question of success of, by Marion E. Jones 432
discussion on question of success of, by E. C. Levy 433
discussion on question of success of, by H. G. H. Nutting 433
Washington, D. C., investigation of underground water waste in 361
method of underground waste investigation 362
water consumption in 361
Waste of metered water, discussion by W. S. Cramer 457
discussion by E. E. Davis 457
discussion by J. M. Diven 457-458
discussion by Robert J. Thomas 457
discussion by W. L. Worrell 457
should reduction be made for 456

Water, classification of, causing hot water troubles 244
consumption of hot and cold 233
effect of heating on quality of 241
methods of heating 233
effect of stagnant on cast iron pipes 47
soft, more corrosive than hard 259
Water analysis, bacterial examination 296
chemical examination 294
microscopical examination 296
physical examination 294
growth in methods of 293
bearing of chlorine on sanitary quality 295
Water consumption, average daily in United States 78
variation in 78
Water mains, carrying capacity of dirty, compared with cleaned 40
corroded not improved by flushing 52
economy effected by cleaning 41
effect of deposit on carrying capacity of 39
effect of stagnation of water on 47
results of cleaning 43
tests for leaks in 364
tests of effect of cleaning 40
Water meters, effect on investment 197
chief function of that of a scare crow 207
make consumers inspectors 207
per centage of under-registration 200
under-registration of 195
under-registration of 206
Water pipe, corrosion of, more rapid after cleaning 48
damage from breaks in large sizes greater, ... 221
effect of cleaning on cast iron at Far Rockaway, N. Y. 49
miles of different sizes in use 97
per centage of different sizes used 96
stress due to backfill important in large size pipes 221
stress produced by fill on 221
Water rates, George G. Earl 173
discussion on by John W. Alvord 189
discussion by Edward W. Bemis 195
discussion by I. B. Brown 203
discussion by J. N. Chester 198
discussion by H. F. Dunham 205
discussion by George G. Earl 213
discussion by Rudolph Hering 210
discussion by H. C. Hodgkins 204
discussion by Theodore Leisen 198–201
discussion by Richard U. Sherman 206
discussion by John C. Trautwine, Jr., ... 207
discussion by Walter L. Watson 198
discussion by Bennezette Williams 201

Water rates, amount necessary to cover installation of service..... 176
cost per thousand gallons decreased with increased consumption.... 182
distinction between public and private use..... 212
compared with mail service..... 203
compared with postal rates..... 201
Dual system would result from flat rate per one thousand gallons. 205
effect of quality on 205
effect of over-built works on..... 184
flat rate cannot be just. 174
flat unfair, wasteful and unjust. 210
flat rate for "service charge" fair..... 211
flat rate not always feasible..... 198
how arrived at in New Orleans..... 178
measure of service to determine 174
minimum annual bill for given size service desirable..... 183
minimum not necessary if meters accurately register small streams. 183
must be based on cost of each item..... 173
must be to manufacturer less than cost of pumping his own supply. 200
necessity of low to some large consumers 202
public institutions metered and charged for..... 183
public and charitable uses should be paid for out of taxes..... 177
regardless of use causes inequity..... 205
report on meter rates at Louisville, Ky..... 190
risk must be eliminated for returns..... 174
service charge at Louisville, Ky..... 192
should sinking fund be included in..... 212
sliding scale not a rebate. 206
small for large consumer necessary to hold needed business..... 199
when service not in use. 191
Water Softening. 425
Water softening by means of Zeolith, by Boris N. Simin..... 347
Water softening, cost of 425
cost of 428
by means of Zeolith cost of..... 452
discussion on advisability of, by Albert Blauvelt..... 426
discussion on advisability of, by E. L. Booth..... 427
discussion on advisability of, by C. A. Broan..... 428
discussion on advisability of, by George J. S. Collins..... 426
discussion on advisability of, by Ernest McCollough 426
discussion on advisability of, by H. G. H. Nutting..... 426
discussion on advisability of, by William Miller Booth..... 425
discussion on advisability of, by William Miller Booth..... 429
discussion on advisability of, by William Holmes..... 425
Water works, estimate of cost of fire protection service..... 83
sub-division of cost of physical plant..... 81
Watertown, N. Y., hot water troubles at..... 249
Watson, Walter, discussion on fire line meters..... 11
discussion on fire line meters..... 12
discussion on water rates..... 198
Weston, Robert Sperr, discussion on hot water problems..... 287

Whipple, George C., paper by, Hot Water Troubles 231
Williams, Benezette, discussion on water rates 201
Wisconsin, hydrant service a public charge 138
Wisconsin railroad commission, position on hydrant rentals 62
Wood stave pipe, discussion by J. M. Diven 170
discussion by T. C. Hatton 171
discussion by Leonard Metcalf 171
carrying capacity of 166
classes of 163
ancient use of 162
copper clad wire use on, in salt marsh 166
cost of 168
cost compared with iron 169
damage to by shipment 163
factor of safety used in designing 166
leakage from 167
limitation of old method of making 162
new method of making 162
pressures it will stand 165
protection of steel bands on 164
tapping of 170
use by El Paso and South Western Railroad 163
use of sawdust to protect bands in shipping 164
Wood stave pipe, some questions answered, by T. Chalkley Hatton 161
Worrell, M. L., discussion on restoration of distribution systems 50
Wrongful use of water from fire services, discussion by Albert Blauvelt .. 454
discussion by Edward L. Hatch 454
discussion by Arthur N. French 455
discussion by Ernest McCollough 455
discussion by F. S. Shields 454
Wrought iron pipe, greater resistance to corrosion than steel 225
use of, at Rochester, N.Y. 286
Zeolith, cost of water softening by 352
sodium in, restored by common salt 349
water softening by means of 347
Zeolith softening plant, description of 350

AUTHORS INDEX

Alvord, John W. Discussion on Question of Washing Filters with Well Water 432
Discussion on Return for Hydrant Service 145
Discussion on Water Rates 189
Bartow, Edward. Discussion on Purification of Drinking Water 314
Bass, Frederick H. Discussion on Emergency Intakes 154
Discussion on Purification of Drinking Water 315
Bemis, Edward W. Discussion on Water Rates 195
Berry, J. P. Discussion on Hot Water Problems 290
Blauvelt, Albert. Discussion on Bronze Valve Stems 455
Discussion on Fire Line Meters 22
Discussion on Furnishing Meter Readings to Consumer 453
Discussion on Joint Connections with Fire Lines 437
Discussion on Leadite for Joints 452
Discussion on Power Calking 439
Discussion on Question of Water Softening 426
Discussion on Return for Hydrant Service 141
Discussion on Saving by Use of Power Driven Trench Pumps 431
Discussion on Wrongful Use of Water from Fire Service 454
Booth, George W. Discussion on Return for Hydrant Service 143
Booth, L. M. Discussion on Question of Water Softening 427
Booth, William Millar. Answer to Question on Water Softening 425–429
Brown, Charles Carroll. METHODS OF KEEPING RECORDS OF IMPROVEMENTS TO ESTABLISH WATER WORKS PLANTS 317
Brown, C. A. Discussion on Question of Water Softening 428
Brown, I. B. Discussion on Return for Hydrant Service 133
Discussion on Water Rates 203
Caulfield, John. Discussion on Fire Line Meters 10
Discussion on Sprinkling Streets by Car Company 459–460
Chester, J. N. Discussion on Fire Line Meters 5–13
Discussion on Hot Water Problems 285–289
Discussion on Pumping Station Management 36
Discussion on Question of Use of Oil for Fuel 433
Discussion on Question of Washing Filters with Well Water 432
Discussion on Restoration of Distributing Systems 48
Discussion on Return for Hydrant Service 130
Discussion on Water Rates 198
Colling, George J. S. Discussion on Question of Water Softening 426
Coventry, H. G. STRIPPING RESERVOIR SITES AT NEWCASTLE, ENGLAND 367
Cramer, W. S. Discussion on Waste of Metered Water 457
Davis, E. E. Discussion on Fire Line Meters 20–22
Discussion on Hammer Testing 459

Davis, E. E. Discussion on Hot Water Problems..... 291
Discussion on Saving by Use of Power Driven Trench Pumps.... 430 431
Discussion on Sprinkling Streets by Car Company..... 460
Discussion on Waste of Metered Water..... 457
Diven, J. M. Discussion on Fire Line Meters..... 22
Discussion on Hot Water Problems..... 279
Discussion on Joint Connections with Fire Lines..... 438
Discussion on Leadite for Joints..... 449–450
Discussion on Question of Washing Filters with Well Water..... 432
Discussion on Waste of Metered Water..... 457–458
Discussion on Wood Stave Pipe..... 170
Downs, John R. Discussion on Question of Oil for Fuel..... 435
Dreyfus, Edward D. Discussion on Steam Turbine Pumps..... 455
Dunham H. F. Discussion on Leadite for Joints..... 451
Discussion on Restoration of Distributing Systems..... 47–51
Discussion on Return for Hydrant Service..... 147
Discussion on Steel vs. Cast Iron Pipe..... 229
Discussion on Water Rates..... 205
Earl, George G. Water Rates..... 173
Discussion on Leadite for Joints..... 450
Discussion on Water Rates..... 213
Ellis, R. N. Discussion on Leadite for Joints..... 452
Ellsworth, Harry. Discussion on Emergency Intakes..... 154
Faller, C. Discussion on Bronze Valve Stems..... 455
Discussion on Furnishing Meter Readings to Consumer..... 454
Discussion on Leadite for Joints..... 452–453
Fisher, A. E. Discussion on Hot Water Problems..... 286
French, Arthur N. Discussion on Application of Hypochlorite..... 443
Discussion on Furnishing Meter Readings to Consumers..... 454
Discussion on Joint Connections with Fire Lines..... 438
Discussion on Leadite for Joints..... 453
Discussion on Metering Non-paying Water Takers..... 442
Discussion on Question of Red Water Troubles..... 437
Discussion on Question of Superintendent's Salary..... 439
Discussion on Saving by Use of Power Driven Trench Pumps..... 431
Discussion on Wrongful Use of Water from Fire Service..... 455
Griswold, F. M. Discussion on Fire Line Meters..... 5–7–9
Gwinn, Dow R. Discussion on Fire Line Meters..... 21
Discussion on Hot Water Problems..... 292
Discussion on Keeping Records of Improvements..... 329
Discussion on Leadite for Joints..... 450
Discussion on Pumping Station Management..... 37
Discussion on Return for Hydrant Service..... 132
Hague, Charles A. High Pressure Fire Service Compared with Portable Fire Engines..... 369
Hatch, Edward L. Discussion on Furnishing Meter Readings to Consumers..... 454
Discussion on Meter Under-Registration..... 456
Discussion on Question of Depth to Lay Mains..... 436
Discussion on Wrongful Use of Water from Fire Services..... 454

Hatton, T. Chalkley. Wood Stave Pipe, Some Questions Answered . 161
Discussion on Reasonable Return for Hydrant Service..... 137
Discussion on Wood Stave Pipe..... 171
Hawley, William C. Some Fundamental Considerations in the Determination of a Reasonable Return for Public Fire Hydrant Service..... 55
Discussion on Fire Line Meters..... 16
Discussion on Leadite for Joints..... 443
Discussion on Reasonable Return for Fire Hydrant Service..... 135
Discussion on Saving by Use of Power Driven Trench Pumps 429
Hazen, Allen. Steel vs. Cast Iron Pipe..... 217
Hering, Rudolph. Discussion on Hot Water problems..... 281
Discussion on Water Rates..... 210
Hill, Nicholas S., Jr. Discussion on Fire Line Meters..... 17
Discussion on Steel vs. Cast Iron Pipe..... 224
Hodgkins, H. C. A Stand Pipe Accident..... 157
Discussion on Restoration of Distributing Systems..... 49
Discussion on Water Rates 204
Hodgman, Burt B. Restoration of Old Distributing Systems..... 39
Discussion on Restoration of Distributing System.....48, 49, 50, 51, 52
Holmes, William. Discussion on Boiler Waters..... 425
Discussion on Question of Success of Washing Filters with Well Water. 432
Hopkins, Charles C. Discussion on Restoration of Distribution Systems 49
Houston, George. Fire Line Meters, A Comparison of Efficiency 1-13
Discussion on Fire Line Meters..... 6
Jackson, Daniel D. Interpretation of Water Analyses 293
Jones, Marion E. Discussion on Question of Washing Filters with Well Water..... 432
Johnson, F. L. Discussion on Question of Use of Oil for Fuel..... 434
Jordan, Frank C. Discussion on Leadite for Joints..... 446
Discussion on Reasonable Return for Hydrant Service..... 133
Kimball, Frank C. Discussion on Return for Hydrant Service 119
Knowles, Morris. Discussion on Emergency Inlets..... 152
Discussion on Return for Fire Service..... 122
Kuichling, Emil. Some Fundamental Considerations in the Determination of a Reasonable Return for Public Fire Hydrant Service... 55
Kunhardt, L. H. Discussion on Fire Line Meters.....7, 9, 10, 11, 18, 19
Lawton, R. W. Some Water Works Experiences in India 353
Leal, Dr. John L. Purification of Drinking Water..... 299
Leisen, Theodore A. Discussion on Water Rates..... 189-201
Levy, E. C. Discussion on Joint Connections with Fire Lines..... 437
Discussion on Question of Success of Washing Filters with Well Water 433
Machen, Henry B. Discussion on Pumping Station Management 38
Mason, Dr. William P. Emergency Intakes..... 151
McCullough, Ernest. Discussion on Furnishing Meter Readings to Consumers 454
Discussion on Question of Depth to Lay Mains..... 436

McCullough, Ernest. Discussion on Question of Water Softening..... 426
Discussion on Saving by Use of Power Driven Trench Pumps..... 431
Discussion on Superintendent's Salary..... 439
Discussion on Wrongful use of Water from Fire Services..... 455
McFarland, W. A. The Investigation of Underground Water Waste in Washington, D. C..... 361
McMillan, Thomas. Pumping Station Management at Milwaukee... 25
Discussion on Pumping Station Management..... 37
Discussion on Restoration of Distribution Systems..... 50
Metcalf, Leonard. Some Fundamental Considerations in the Determination of a Reasonable Return for Public Fire Hydrant Service..... 55
Discussion on Joint Connections with Fire Lines..... 438
Discussion on Leadite for Joints..... 448–450
Discussion on Pumping Station Management..... 37
Discussion on Return for Hydrant Service..... 141
Discussion on Return for Fire Hydrant Service..... 117
Discussion on Wood Stave Pipe..... 171
Maury, Dabney H. Discussion on Panama Canal..... 53
Milne, Alexander. Compressed Air in Water Works Construction. 337
Discussion on Compressed Air on Water Works Construction..... 339
Discussion on Hammer Testing..... 458
Discussion on Metering Non-paying Water Takers..... 441
Discussion on Sprinkling Streets by Car Company..... 459
Nutting, H G. H. Discussion on Bronze Valve Stems..... 455
Discussion on Depth to Lay Mains..... 436
Discussion on Furnishing Meter Readings to Consumers..... 454
Discussion on Leadite for Joints..... 452–453
Discussion on Question of Red Water Troubles..... 437
Discussion on Question of Success of Washing Filters with Well Water. 433
Discussion on Question of Water Softening..... 426
Discussion on Saving by Use of Power Driven Trench Pumps..... 431
Peeler, R. L. Discussion on Furnishing Meter Readings to Consumers. 454
Powell, S. T. Sterilization of Water by Ultra Violet Rays..... 341
Reimer, A. A. Discussion on Fire Line Meters..... 16
Discussion on Furnishing Meter Readings to Consumers..... 453
Discussion on Leadite for Joints..... 447–448
Salmon, C. B. Discussion on Reasonable Return for Hydrant Service... 138
Shaw, Mr. Discussion on Leadite Joints..... 451
Sherman, Richard U. Discussion on Water Rates..... 206
Shields, F. S. Discussion on Meter Readings to Consumers..... 454
Discussion on Metering Non-Paying Water Takers..... 442
Discussion on Question of Red Water Troubles..... 437
Discussion on Wrongful Use of Water from Fire Services..... 454
Simin, Boris N. Water Softening by Means of Zeolith..... 347
Smith, Charles W. Sydney Water Supply..... 393
Smith, W. Z. Discussion on Restoration of Distribution Systems..... 52
Speller, Mr. Discussion on Hot Water Problems..... 283
Stedman, B. F. Discussion on Hot Water Problems..... 291

Thomas, Robert J. Discussion on Fire Line Meters..... 19
Discussion on Waste of Metered Water..... 457
Trautwine, John C., Jr. Discussion on Metering Non-Paying Water Takers..... 441
Discussion on Water Rates..... 207
Van Gilder, L. Discussion on Wood Stave Pipe..... 172
Walden, A. E. Sterilization of Water by Ultra Violet Rays..... 341
Discussion on Application of Hypochlorite..... 442
Discussion on Furnishing Meter Readings to Consumers..... 453
Discussion on Metering Non-Paying Water Takers..... 442
Discussion on Power Calking..... 439
Discussion on Question of Use of Oil for Fuel..... 434
Discussion on Steam Turbine Pumps..... 455
Watson, Walter L. Discussion on Fire Line Meters..... 11–12
Discussion on Water Rates..... 198
Wehr, Albert H. Discussion on Saving by Use of Power Driven Trench Pumps..... 430
Discussion on Restoration of Distribution System..... 53
Weston, Robert Spurr. Discussion on Hot Water Problems..... 287
Discussion on Leadite for Joints..... 448
Discussion on Saving by Use of Power Driven Trench Pumps..... 429 431
Whipple, George C. Hot Water Troubles..... 230
Discussion on Hot Water Problems..... 289
Williams, Bennezette. Discussion on Water Rates..... 201
Wills, C. W. Discussion on Saving by Use of Power Driven Trench Pumps..... 430
Worrel, M. L. Public Utilities..... 331
Discussion on Leadite for Joints..... 450
Discussion on Restoration of Distribution System..... 50
Discussion on Waste of Metered Water..... 457
Yeagar, A. J. Discussion on Leadite for Joints..... 447

INDEX TO ADVERTISEMENTS

Allis-Chalmers Co. 37-a
Alvord, John W. 34-a
American Asphaltum & Rubber Co. 47-a
American Cast Iron Pipe Co. 41-a
American Pipe & Construction Co. 43-a
American Society of Mechanical Engineers 48-a
Anderson Coupling Co. 24-a

Bourbon Copper & Brass Works Co. 26-a
Buffalo Meter Co. 14-a
Builders Iron Foundry Co. 42-a
Burdick, Charles B. 34-a

Caird, James M. 33-a
Canadian Engineer 3-a
Cassier's Magazine 4-a
Chapman Valve Mfg. Co. 26-a
Chicago Bridge & Iron Works 29-a
Clark, William G. 34-a
Clark Co., H. W. 26-a
Colorado Fuel & Iron Co. 44-a
Conrad, William R. 34-a

Darling Pump & Mfg. Co. 26-a
Drummond & Co., M. J. 42-a

Eastern Manufacturing Co. 41-a
Engineering Magazine 5-a
Engineering News 7-a
Engineering Record 8-a
Engineering & Contracting 6-a

Farnan Brass Works 23-a
Fuller, George W. 34-a

Gamon Meter Co. 15-a
General Chemical Co. 45-a
Glauber Brass Mfg. Co. 25-a
Gonden, H. J. 11-a

Harrison Bros. & Co. 46-a
Hersey Manufacturing Co. 16-a
Hill Publishing Co. 9-a

Jarecki Chemical Co. 32–a

Kellogg & Co., E. H. 13–a
Kennedy Valve Mfg. Co. 39–a

Ludlow Valve Mfg. Co. 36–a

Maury, Dabney H. 33–a
Modern Iron Works 24–a, 26–a, 33–a
Mueller Mfg. Co., H. 27–a
Municipal Journal 10–a

National Meter Co. 17–a
National Water Main Cleaning Co. 35–a
Nep une Meter Co. 18–a
New Brunswick Iron Works 28–a
New York Continental Jewel Filtration Co., The 30–a

Pennsylvania Salt Mfg. Co. 31–a
Pitometer Co. 35–a
Pittsburgh Filter Co. 32–a
Pittsburgh Meter Co 19–a
Potter, Alexander, C. E. 34–a
Potts, Clyde 34–a
Power 9–a
Public Service 11–a

Ross Valve Mfg. Co. 37–a

Salmon, Frederick William 48–a
Smith, Mfg. Co. A. P. 24–a

Taylor, Samuel A. C. E. 34–a
Taylor Co., W. P. 22–a
Thompson Meter Co. 20–a

Union Water Meter Co. 22–a
United States Cast Iron Pipe & Foundry Co. 40–a

Water & Gas Review 12–a
Water Works Supply Corporation 31–a
Weston, Edmund B. 33–a
Weston, Robert Spurr 33–a
Wood & Co., R. D. 38–a
Worthington, Henry R. 21–a

CLASSIFIED INDEX TO ADVERTISEMENTS

BRASS FITTINGS

Anderson Coupling Co. 24-a
Farnan Brass Works 23-a
Glauber Brass Mfg. Co. 25-a
Mueller Mfg. Co., H. 27-a
Union Water Meter Co. 22-a
Smith Mfg. Co., A. P. 24-a

CURB BOXES

Taylor & Co., W. P. 22-a

ENGINEERS—CONTRACTING AND CONSULTING

Alvord, John W. 34-a
American Pipe & Construction Co. 43-a
Burdick, Charles B. 34-a
Caird, James M. 33-a
Clark, William G. 34-a
Conrad, William R. 34-a
Fuller, George W. 34-a
Maury, Dabney H. 33-a
Potter, Alexander, C. E. 34-a
Potts, Clyde 34-a
Salmon, Frederick William 48-a
Taylor, Samuel A. 34-a
Weston, Edmund B. 33-a
Weston, Robert Spurr 33-a

FILTERS AND FILTER SUPPLIES

General Chemical Co. 45-a
Harrison Brothers & Co. 46-a
Jarecki Chemical Co. 32-a
New York Continental Jewel Filtration Co., The 30-a
Penn Salt Mfg. Co. 31-a
Pittsburgh Filter Mfg. Co. 32-a
Water Works Supply Corporation 31-a

FLOOR STANDS

Darling Pump & Mfg. Co. 26-a

FLUSH TANK REGULATORS

Modern Iron Works 33-a

HYDRANTS

Bourbon Copper & Brass Works Co. 26–a
Darling Pump & Mfg. Co. 26–a
Drummond & Co., M. J. 42–a
Kennedy Valve Mfg. Co. 39–a
Ludlow Valve Mfg. Co. 36–a
Wood & Co., R. D. 38–a

INDICATOR POSTS

Bourbon Copper & Brass Works Co. 26–a
Darling Pump & Mfg. Co. 26–a
Ludlow Valve Mfg. Co. 26–a
Wood & Co., R. D. 38–a

LUBRICANTS AND PACKING

Kellogg & Co., E. H. 13–a

METERS

Buffalo Meter Co. 14–a
Gamon Meter Co. 15–a
Hersey Mfg. Co. 16–a
National Meter Co. 17–a
Neptune Meter Co. 18–a
Pitometer Co. 35–a
Pittsburgh Meter Co. 19–a
Thomson Meter Co. 20–a
Union Water Meter Co. 22–a
Worthington, Henry R. 21–a

METER BOXES

Clark Co., H. W. 26–a

PERIODICALS

Canadian Engineer 3–a
Cassier's Magazine 4–a
Engineering Magazine 5–a
Engineering News 7–a
Engineering Record 8–a
Engineering & Contracting 6–a
Municipal Journal 10–a
Power 9–a
Public Service 11–a
Water & Gas Review 12–a

PIPE AND SPECIALS

American Cast Iron Pipe Co ... 41-a
Colorado Fuel & Iron Co. ... 44-a
Drummond & Co., M. J. ... 42-a
Eastern Manufacturing Co. ... 41-a
United States Cast Iron Pipe & Foundry Co. ... 40-a
Wood & Co., R. D. ... 38-a

PIPE CLEANING

National Water Main Cleaning Co. ... 35-a

PIPE COATING

American Asphalt & Rubber Co. ... 47-a

PIPE LOCATORS

Modern Iron Works ... 24-a
Positions Wanted ... 49-a

PUMPING ENGINES

Allis-Chalmers Co. ... 37-a
Wood & Co., R. D. ... 38-a

SLEEVES

New Brunswick Iron Works ... 28-a
Smith Mfg Co., A. P. ... 24-a

TANKS

Chicago Bridge & Iron Works ... 29-a

TAPPING MACHINES

Smith Mfg. Co., A. P. ... 24-a

VALVES

Bourbon Copper & Brass Works ... 26-a
Chapman Valve Mfg. Co. ... 26-a
Darling Pump & Mfg. Co. ... 26-a
Drummond & Co., M. J. ... 42-a
Kennedy Valve Mfg. Co. ... 39-a
Ludlow Valve Mfg. Co. ... 36-a
Ross Valve Mfg. Co. ... 37-a
Smith Mfg. Co., A. P. ... 24-a
Wood & Co., R. D. ... 38-a

VALVE BOXES

Bourbon Copper & Brass Works..... 26–a
Darling Pump & Mfg Co..... 26–a
Drummond & Co., M. J..... 42–a
Modern Iron Works..... 26–a

WATER MOTORS

Smith Mfg. Co., A. P..... 24–a

WATER WORKS SUPPLIES

Darling Pump & Mfg. Co..... 26–a

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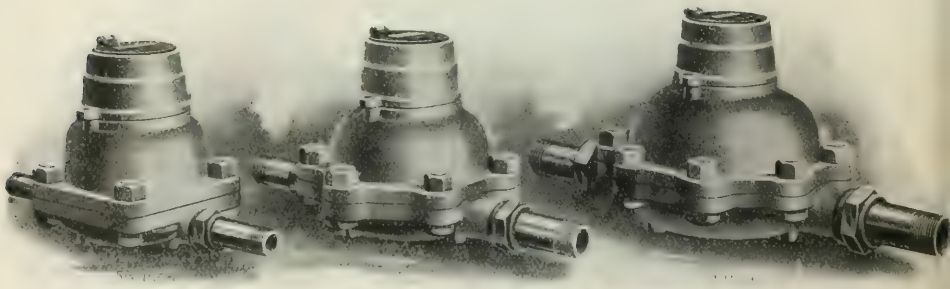

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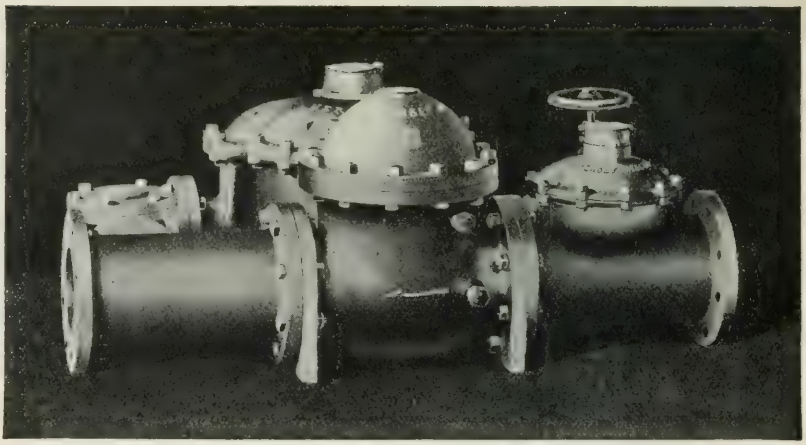

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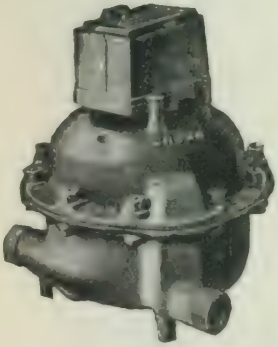

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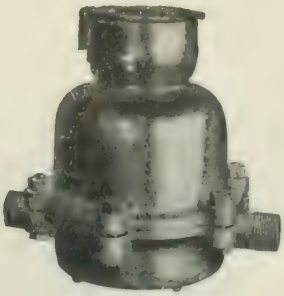

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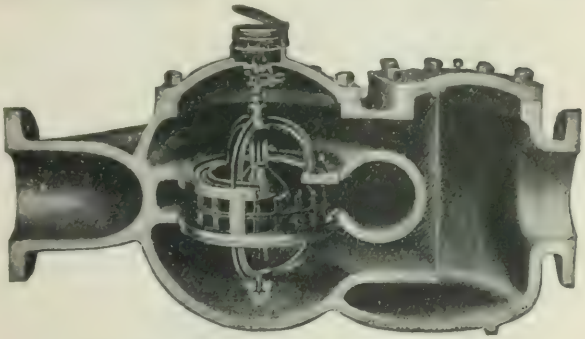

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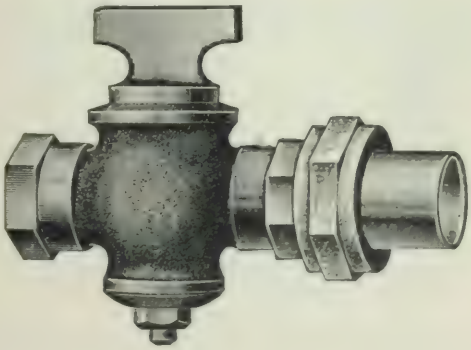

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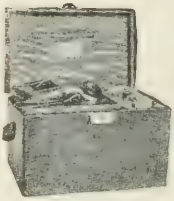

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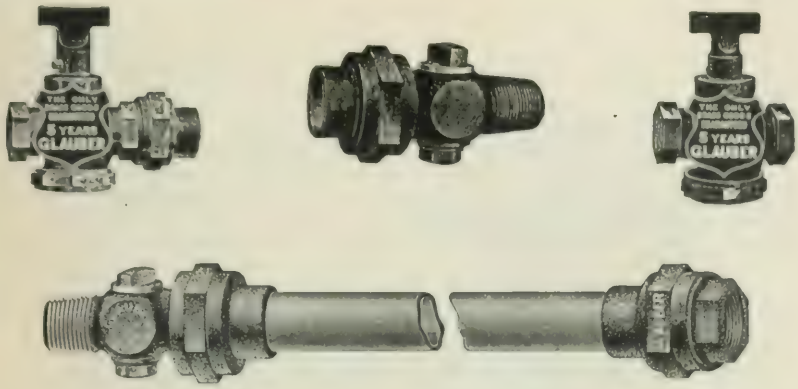

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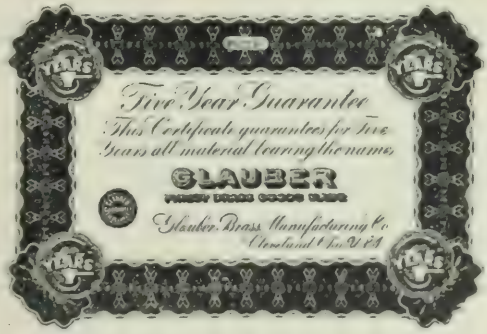

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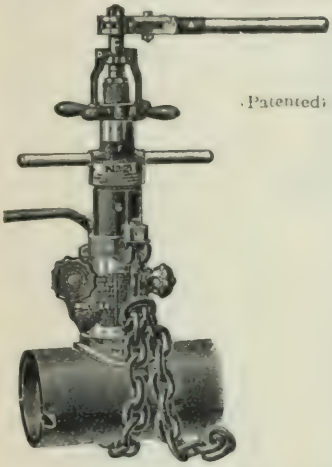

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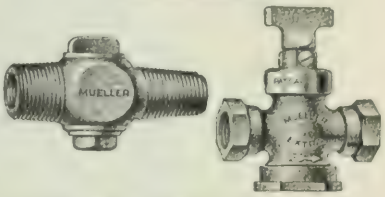

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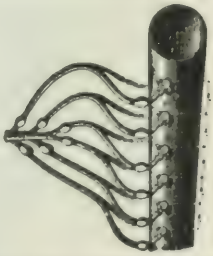

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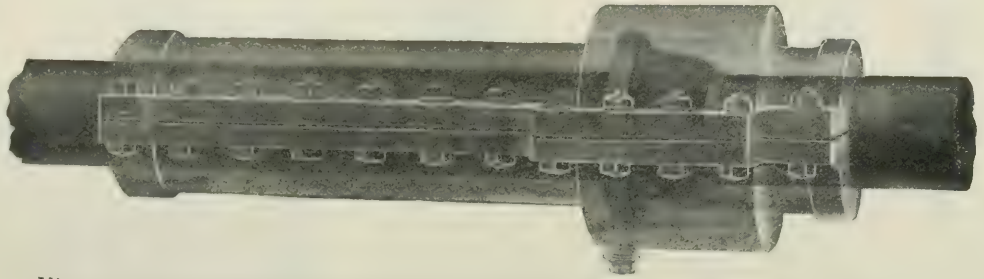

View showing cracked pipe covered by "THE KELLOGG BELL REPAIR SLEEVE"

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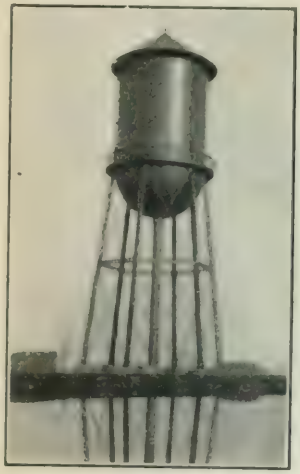

Homestead Water Works
Cap. 200,000 Gal.
Height 100 Ft.

Years	Million Gals. Pumped	Billion Foot Lbs.	Total Cost of Fuel	Cost per Billion Ft. Lbs.
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1900	118.2	100	2345	23.45
1901	139.1	94	2852	30.50
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1903	243.7	290	2508	8.65

Note: During 1899 and a portion of 1900 a wood tank was being used. This leaked so badly that it was abandoned and the system operated by direct pressure until January, 1902, when a steel tank was put into service.

These figures were compiled from the monthly reports covering the entire period.

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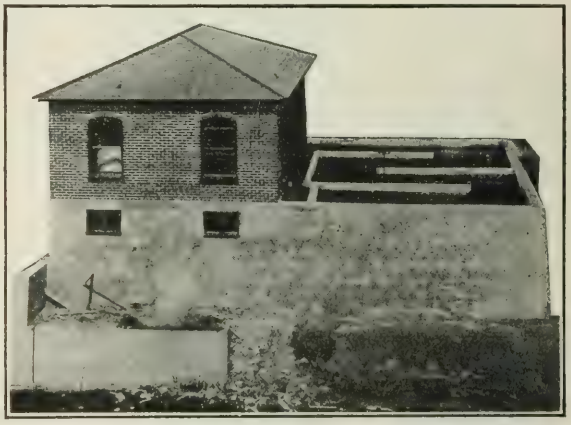

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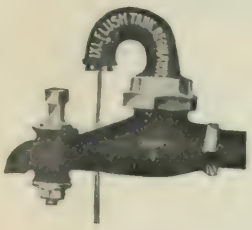

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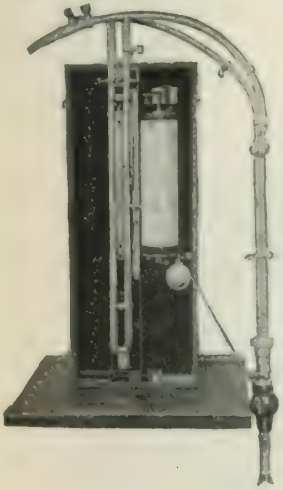

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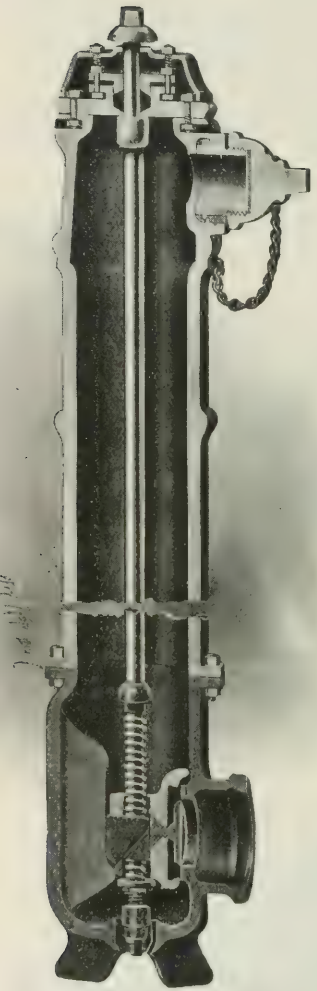

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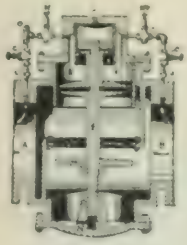

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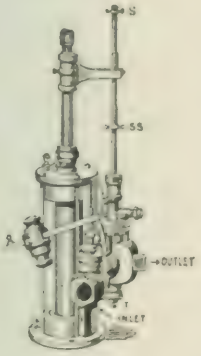

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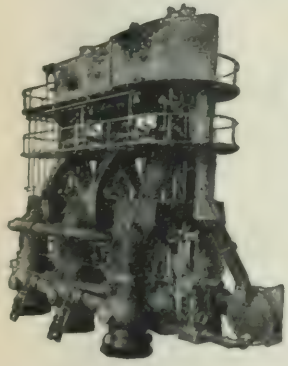

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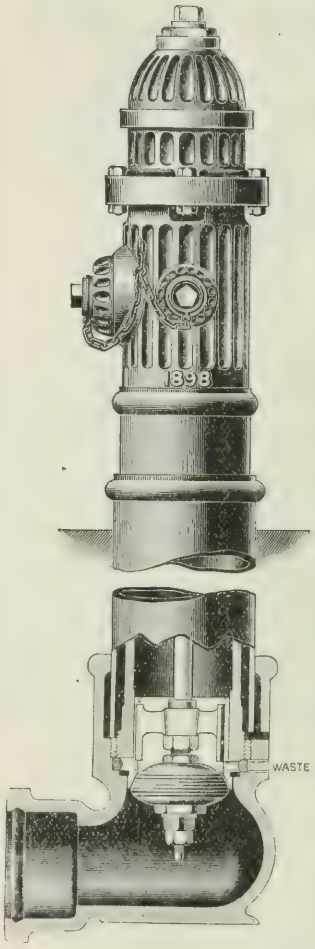

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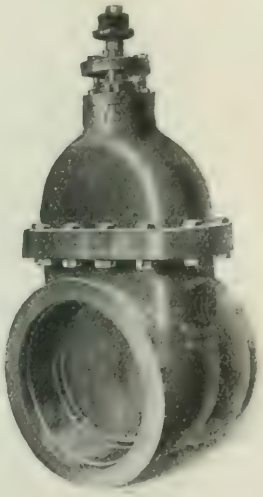

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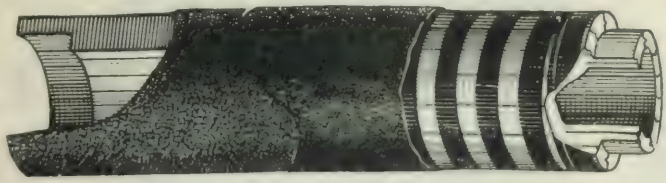

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